COMBUSTION

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East River Station, New York Edison Company

Heat Absorbing Surfaces in Modern Boiler Furnaces

By R. J. S. PIGOTT

Problems of Design in Vessels for High Pressures and Temperatures

By J. B. CRANE

Other Articles in This Issue by

DAVID BROWNLIE • B. J. CROSS • CARL STRIPE • T. A. MARSH

1400-lb. pressure at Milwaukee

At Lakeside Station, the Milwaukee Electric Railway & Light Company is installing a Combustion Steam Generating unit capable of delivering 250,000 pounds of steam per hour and designed for a maximum pressure of 1400-lb. gage.

This unit is equipped with C-E Fin Tube water-cooled furnace walls, C-E plate type Air Preheater and is fired by a Lopulco pulverized fuel system of the storage type.

The Milwaukee Electric Railway & Light Company was the first public utility company to adopt pulverized fuel firing. The use of high steam pressure at Lakeside again evidences the progressive spirit of that organization.

This high pressure unit is an excellent example of coordinated design. The complete fuel burning and steam generating equipment was sold under one contract—one responsibility and one set of guarantees.

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COMBUSTION

Vol. 1 JULY 1929 No. 11

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Campbell Soup's First Thought

"Throughout the design the first thought was simplicity and assurance against shutdown."

* * *

There is the keynote of POWER'S description (Feb. 12, 1929 issue) of the new plant of Campbell Soup Company at Thirty-fifth and Rockwell Streets, Chicago.

There is the principle guiding the consulting engineers, Battey and Kipp, Inc., Chicago, in the layout and design of the power plant.

There is a dominating thought which will almost invariably lead to the selection, as in the Campbell Soup plant, of Detrick Arches and Walls *for simplicity and assurance against shutdown.*

* * *

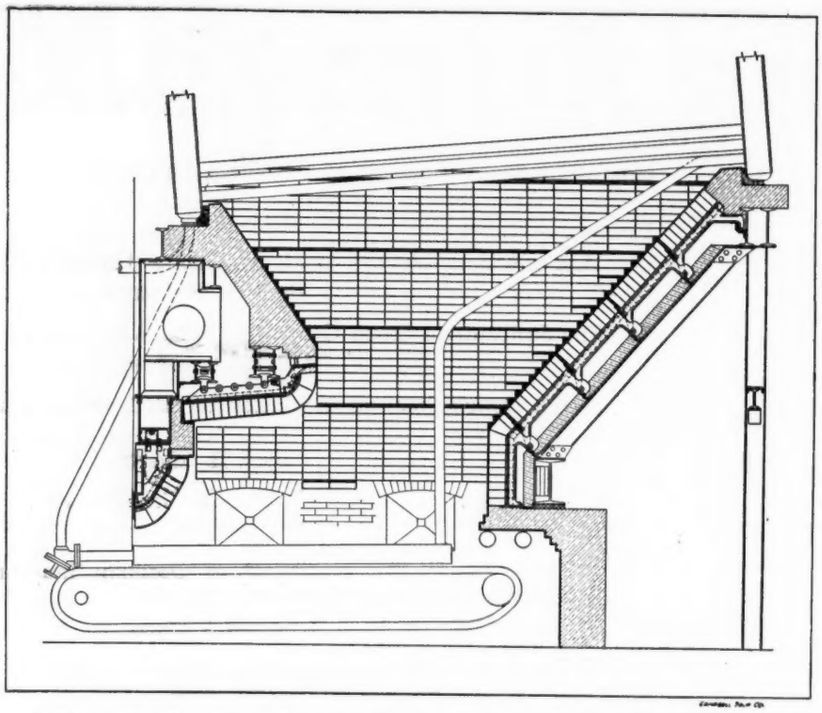
In the Campbell design, the consulting engineers have taken full advantage of the Detrick principle of thorough wall ventilation. Air circulated by pressure around the Detrick Air-Cooled Wall and collected in a large plenum box in front is discharged over-fire, this salvage of warm air proving "a great help to efficient and smokeless combustion."

* * *

"Air preheaters were considered," says POWER, "but despite the increased efficiency obtainable were omitted." Maximum use of the possibilities in Detrick wall design thus permitted the conservation of building space and made for extremely low plant maintenance. A Detrick installation, always largely of stock materials, is simplicity itself. And assurance against shutdown is obvious from these long-life, steady-performance features:

1. Refractory load supported from outside in small sections.
2. Positive allowance for vertical and horizontal expansion.
3. Rapid internal cooling of refractory tile through finned hanger bars.
4. External cooling through air circulation.
5. No sagging or bulging.
6. Finest refractory obtainable.

The more discriminating the engineer, the surer we are of the *first* order. The repeats come almost automatically.



"Simplicity and Assurance Against Shutdown" —Naturally Detrick Got the Job!

Detrick Wall and Detrick Convex-Concave Arch at Campbell Soup Plant, Chicago. Warming of over-fire air by Detrick air-cooling process provides high efficiency coupled with compactness, low first cost and low plant maintenance.

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DETRICK ARCHES & WALLS

"Better than the Refractory of which They are Made"

COMBUSTION

Vol. 1 July 1929 No. 1

A Statement of Ownership and Policy

THIS is the first issue of COMBUSTION—a new magazine—published by In-ce-co Publishing Corporation, a subsidiary of International Combustion Engineering Corporation.

The accurate interpretation and dissemination of news concerning present-day practice, new developments and future trends in the fields of fuel burning and steam generation are matters of vital importance both to the manufacturers who have contributed to this progress and to the engineers who seek to take advantage of the improvements made in methods and equipment. An authoritative publication, which will devote itself specifically to the purpose of describing and discussing these developments, can, therefore, serve a very useful purpose.

As the largest organization, engaged in the manufacture of fuel burning and steam generating equipment, International Combustion Engineering Corporation regards the issuing of such a publication as peculiarly its responsibility.

This first issue of COMBUSTION reflects its editorial policy—to publish authoritative articles which will serve to keep all those interested in this field informed of what is being done and what the future trends are. The editorial pages of the magazine will be educational in a broad sense and helpful in a practical way. The authors will include men who are publicly recognized as the leaders of thought in their respective fields.

The principal aim of COMBUSTION will be realized if it effects a broader understanding of the important developments that are constantly taking place in this field, and thus contributes to the more extended use of better principles and practice in the arts of fuel utilization and steam generation.

·EDITORIAL·

Politics

IT IS evident that the public utility companies in Wisconsin are not going to surrender passively and let the politicians take over their business.

The utility companies have submitted to the state Judiciary Committee a mass of data and charts, proving in detail that clean government in Wisconsin may easily be eradicated, that taxes will be increased tremendously, that home rule will be wiped out and that the most powerful and menacing political machine in the state's history will be created if municipal ownership bills are passed. They have submitted data to show that in the nation and in the state of Wisconsin the average rates of plants operated under municipal ownership are 1½ cents per kilowatt hour higher than those under private ownership.

The politicians are using the much discussed low rates in Ontario from the Canadian part of the Niagara Falls power development, and the companies reply, "Physical conditions, and bookkeeping and operating practices that would not be tolerated in Wisconsin, are the two things responsible for low rates in Ontario."

Thomas A. Edison recently summed up the inevitable outcome of governmental operation of any business by reminding us that the deficits are paid by taxes.

And, of course, there never is a profit.

There is no impelling commercial incentive for research and experimental work for the development of improved apparatus and more efficient operating methods. Thus, under government control, there is lacking that great stimulus which, during the past decade, has cut in half the coal consumption per kilowatt hour of our public utility plants.

Business development of natural resources is always on a competitive basis, whether the competition is obvious or not. Business takes the risk, pits its brains and energy against loss. When it wins, and shows a profit, it has helped greatly to raise the standards of living for all of us, has developed more high grade captains of industry, and has usually contributed to civilization the greatest amount of good at the least possible cost.

Hydro vs. Steam

THE spirited argument over hydro versus steam electric power has two sides, not one. It is not always easy to analyze statistics with absolute fairness. Too many of us are prejudiced, because we have a dollar and cents reason for so being.

One argument is over the relative costs of the two methods of producing electric current. It manifestly isn't fair to compare the star plant of the one against the average plant of the other. It is not at all certain that any very useful conclusion is reached even by comparing the record plants of both methods.

Another argument is over the relative or proportional gain in new plant capacity. The United States Geological Survey figures show a larger recent gain by hydro than by steam. But steam proponents point out that today's hydro plant was planned five years ago, and claim that today's new projects point to a gain in steam.

COMBUSTION is interested in steam electric generation rather than in hydro. But it is not particularly concerned about the arguments referred to. It is, however, tremendously interested in the continued improvement in steam plants, and it is furthering such improvement by the dissemination of all legitimate information that will help raise the steam plant to higher economies.

Let those who will, support the claims of hydro. The great law of economics will be the judge, and the judgment will be separately rendered for each specific case, with due consideration of the factors of investment, fuel and power transmission. If hydro can produce power at a lower over-all cost to the ultimate consumer, the palm will go to it. If steam can show the lower over-all cost, then it will sit secure in the seat of the victor. Our activity will be devoted to new records by steam, continued improvement in the steam plant, and our utmost contribution to further advances in the economical use of coal.

This Month's Cover

THE illustration on the front cover of this issue of COMBUSTION is of the East River Station of the New York Edison Company, and is reproduced from an original etching by O. Kuhler, one of America's foremost etchers of industrial subjects.

The East River Station is one of the outstanding achievements in the public utility field.

The 150,000 k.w. turbo generator now being installed at this plant is the largest single shaft single-unit generator ever built.

The new boilers for this station will each be capable of delivering 800,000 pounds of steam per hour—a record steaming capacity for individual units.

The ultimate capacity for which the East River Station is designed will make it the largest electrical generating station in the world.

Heat Absorbing Surfaces in Modern Boiler Furnaces

By R. J. S. PIGOTT
Consulting Engineer, Stevens & Wood, Inc., New York

THE primary purpose for heating-surface in the furnace was originally to protect refactories, thus reducing maintenance and presumably increasing reliability. Stokers were developed over a number of years without any furnace cooling except that due to the bottom rows of boiler tubes, and maintenance troubles were divided between burning of the grates or tuyeres and ruined brickwork, from fluxing or clinker adherence. In some of the installations using low-grade coals high in sulphur and with low fusion ash, it appeared almost as if the combustion operation consisted of burning equal parts of coal, iron and brick. Perhaps the earliest systematic attempt at protection of brickwork was the side wall and front wall ventilation installed by the writer in the Dayton Power & Light Company plant in 1912. The gain in protection was enormous, and there were some incidental advantages in efficiency. Various systems have since been developed to reduce wall ventilation to a standardized construction.

Economy demands the fullest possible use of equipment which in the large plant may run into hundreds of thousands of dollars. Boiler outage due to furnace maintenance is prohibitive. Mr. Pigott shows why the heat absorbing surface in boiler furnaces is necessary, and how it has been successfully applied in several installations. He has also frankly discussed the engineering problems involved, so that the subject matter is timely as well as impartial.

The advent of powdered coal into power station construction almost immediately occasioned a search for better furnace protection. Since pulverized fuel is very near in behavior to a good oil or gas fire, it could be burned with a very low excess air. The average in stoker performance was seldom less than 40 per cent excess air (say 13 per cent CO_2) and generally 45 to 50 per cent. With powdered coal 20 per cent down to 10 per cent was soon secured. Naturally the reduction of excess air raised the furnace temperature considerably, resulting in rapid erosion of brickwork and heavy slagging with low-fusion ash coals, due to the fact that furnace temperature near the walls exceeded the fusion point of the ash.

For some time this condition was met by keeping the excess air nearly up to that for a stoker (13¼ to 14 per cent CO_2) or else keeping the B.t.u. release rate down to 15,000 or 16,000 B.t.u. per cubic ft. per hour. Another expedient was the use of the so-called long-flame burner, in which the peak temperature obtainable with 100 per cent air is depressed 200 or 300 degrees by delaying the combustion. The combustion is delayed and the flame lengthened since only 15 to 20 per cent of the required air is available at the start, the remainder being bled in as the flame proceeds along its path. The only places where there is enough air to complete the combustion are toward the tip of the flame and at the fringe of the flame along the bottom and sides. The length of the flame (60 to 75 ft.) necessitated large furnaces, up to 65 cu. ft. per 1000 lb. of steam—but even this size of furnace would not prevent slagging of ash at the bottom of the furnace: the bottom water screen, quickly followed by the back water-wall, was applied to correct this condition. There was a marked improvement in ability to carry higher CO_2 without slagging, although the B.t.u. release rate was still low. Furnace maintenance was reduced.

At this point, engineers generally began to worry about the possibility of over-cooling the furnace and causing smoke and incomplete combustion. Apparently much of the available information of earlier boiler installations was neglected; we have had 100 per cent cooled furnaces in Scotch boilers and locomotives for several generations. Hand fires, stokers, oil and powdered coal have all been successfully used in all-cold furnaces as low as three feet diameter. All of these can be, and have been, operated without smoke, although they are on the border line of stable operation, and will smoke readily if badly handled.

The reason why furnace cooling need have only a negligible effect can be readily perceived by a consideration of the available facts. Smoke, the earmark of imperfect combustion, is caused by two things only: each related to the supply of air, and due either to actual shortage or to imperfect mixture (stratification) and temperature below the ignition point. Experimental data show that in any furnace the depression of furnace temperature near any "cold" surface only extends to a depth of 2 to 4 feet; after that it is indistinguishable and the flame temperature is at its natural level unless there is heat absorption. While all gases radiate heat, the CO_2 and water vapor are the particularly radiant gases in a furnace and are the source of a certain part of the heat radiated. The carbon particles form the bulk of the luminosity and supply the larger part of the heat radiated, while at the same time they are

themselves highly opaque. The net result is that in any furnace larger than 8 or 10 ft. cube, with any degree of furnace turbulence and good mixture of air and fuel, there need be no trouble from smoke and incomplete combustion. In power work, we are practically always dealing with furnaces larger than 12 ft. cube, and therefore the question of smoke becomes solely one of the design of the burner and the quality of operation.

We have modern proof that this is so in several operating installations, all more than 90 per cent cold furnace. Fig. 1 shows the 14th Street Station of New York Edison Company with full cold fin-tube walls and long flame burners; Fig. 2 shows the Kips Bay installation, New York Steam Corporation, with the same kind of furnace; Fig. 3 shows boilers No. 5

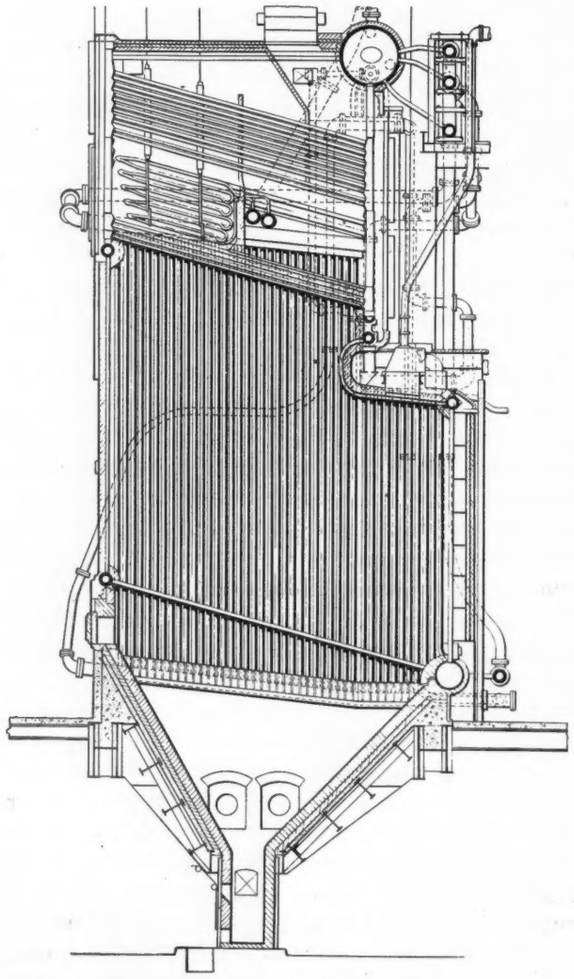


Fig. 1—Boilers at 14th Street Station New York Edison Company

and No. 6 at Toronto Station, Ohio River Edison Company, with covered tubes; Fig. 4 shows the boilers at Cahokia Station, St. Louis, with bare close spaced tubes; Fig. 5 shows the Kearny Station boilers, Public Service of New Jersey, with close spaced bare tubes, of the bifurcated type, covered with cast iron block for three feet up from the stoker.

All of these boilers are operated without appreciable smoke over that perceptible with a full refractory furnace. The question of smoke is one of operation and nothing else. In the case of Kearny, the comparison can be made at any time since the first twelve boilers are fired with the same type stokers, each group on separate stacks, no furnace cooling; the three full-cooled furnaces are on a third stack. There is no difference in average smoke from any of the stacks.

The obvious reasons for use of full cooling are: Increase of steaming capacity for unit volume; decrease of furnace maintenance; decrease of furnace slagging troubles; decrease of outage; decrease of boiler slagging. Steaming capacity can, of course, be greatly increased by furnace walls; in the installations shown in the illustrations the water walls and screens may rate, in full tube surface, as much as 35 per cent of the boiler surface. In the Toronto original installation 10 per cent of bare tube surface does 30 per cent of the work of the boiler unit, at full load.

The use of water-walls is much like wrapping the boiler around the furnace; whatever heat absorption occurs in the walls reduces the heat absorption required of the boiler. If the boiler is kept the same size, the exit gas temperature is lowered or the boiler may be reduced in surface to keep the gas temperature the same for the preheaters or economizers. Cost in this case is lowered.

It has been said that adding water wall surface is equivalent to adding the same surface in the last pass of the boiler. If the boiler arrangement is left the same, merely cutting out tube rows, this statement is nearly true. But a proper design would provide for shortening the tubes or narrowing the boiler so as to increase the gas velocities to bring the draft loss back to the same value, in which case the heat transfer rate in the boiler is increased and the surface added in the furnace is much more effective than adding the same amount in the last pass.

So far as the furnace is concerned, the use of full cooling permits a very large increase in B.t.u. release rate without slagging. The furnace cooled with back and bottom screens was limited to 16,000 to 18,000 B.t.u. per cu. ft. The first Toronto installation was for a long time the high spot for long flame burners. This had cooling on all sides except the front wall, and reached 30,000 B.t.u., usual maximum 28,000.

The full cooled installations, especially with turbulent burners, operate as high as 60,000 B.t.u. The furnace volume for a given output is correspondingly reduced, cutting the building space required. The cost per 1000 lbs. of steam is slightly less for the full water walls, and the total cost of the plant is noticeably less.

As practically all brickwork is eliminated, furnace maintenance is almost wiped out. Since the temperature of the furnace near the walls is reduced to about 1800 or 1900 degrees, slagging can be com-

pletely eliminated. With high ratings, slagging of the boiler tubes was a distinct limitation, and resulted in high draft loss and reduced capacity, es pecially with stokers. A good illustration of this

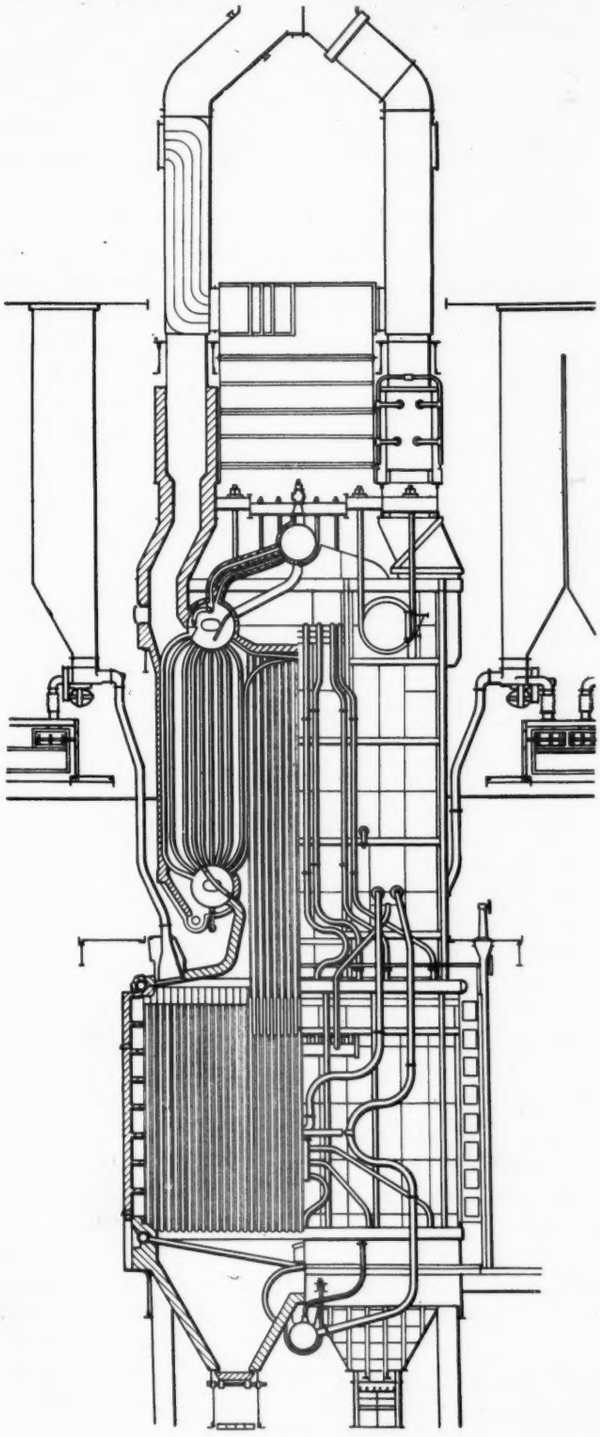


Fig. 2—Kips Bay Boilers
New York Steam Corporation

condition may be drawn from Kearny. In the original installation with stokers, no wall-cooling, and horizontal baffle two tubes up, the boilers would plug in a few hours at ratings above 225 per cent. Raising the baffle to the sixth row, and changing tuyeres on the stoker allowed operation up to 350 per cent, but lancing is done on the bottom rows at least once a week. On the new boilers with 90 per cent cooling, no lancing is done and there are practically no slag accumulations on the slag screen. Most of the dust now sails through the new boilers and is collected in the stack. The difference is entirely due to the condition of the fly-ash. In the old boilers the furnace temperature went above 2400 degrees at the slag screen and the fly-ash was then plastic and would stick. In the new boilers the temperature at the slag screen does not exceed 2150 or 2200 degrees, and the ash is dry. The effect on outages from slagging and brickwork is very evident.

Another advantage, so often noticed, is the reduction of boiler radiation: surrounding the furnace with water-walls reduces the outside temperature of the furnace wall very greatly. At Kearny no point on the outer surface of the walls is too hot for the hand. Carrying the water-walls to the top of the boiler in a modified form has eliminated buckstays and reduced thickness of all walls from 22½ inches in the older installation to 9½ inches. The space thus released is very useful for soot blower piping and other accessory equipment around the boiler.

A further advantage appears in tighter settings; the water-wall breathes with the boiler, consequently the expansion between brickwork, baffles and walls is eliminated. Differential expansion between insulation back of the water-walls and the tube is so uniformly spread that the ordinary insulation materials will not show cracks.

Water-walls are divided into two major classes, bare and covered; the great word-war is waged between the exponents of the two systems.

The hypotheses back of the two types are necessarily involved, because we are using the furnace for two distinct functions: a place to generate heat, and a place to absorb it. Many of the things that should be done for a good fire are opposed to the things we would like to do for the heating surface. If we could design the ideal boiler and furnace we should generate heat in a chamber kept as hot as possible, with no cooling, all the air at once, and violently agitated; the heat to be absorbed in another chamber kept cold enough to dry the ash, and no combustion whatever. Practical considerations have prevented us from building such a design; the nearest approach was the uncooled well-type furnace, which has been modified out of recognition from the original scheme.

The arguments advanced for the covered wall are:

1. The furnace should be as hot as possible to accelerate combustion and to keep the ash fluid for tapping.
2. The tubes will be injured (in high pressure boilers) by direct exposure to flame, due to difference in temperature between inside and

outside, producing heavy internal stresses in the tube.

3. The flame should not come in contact with

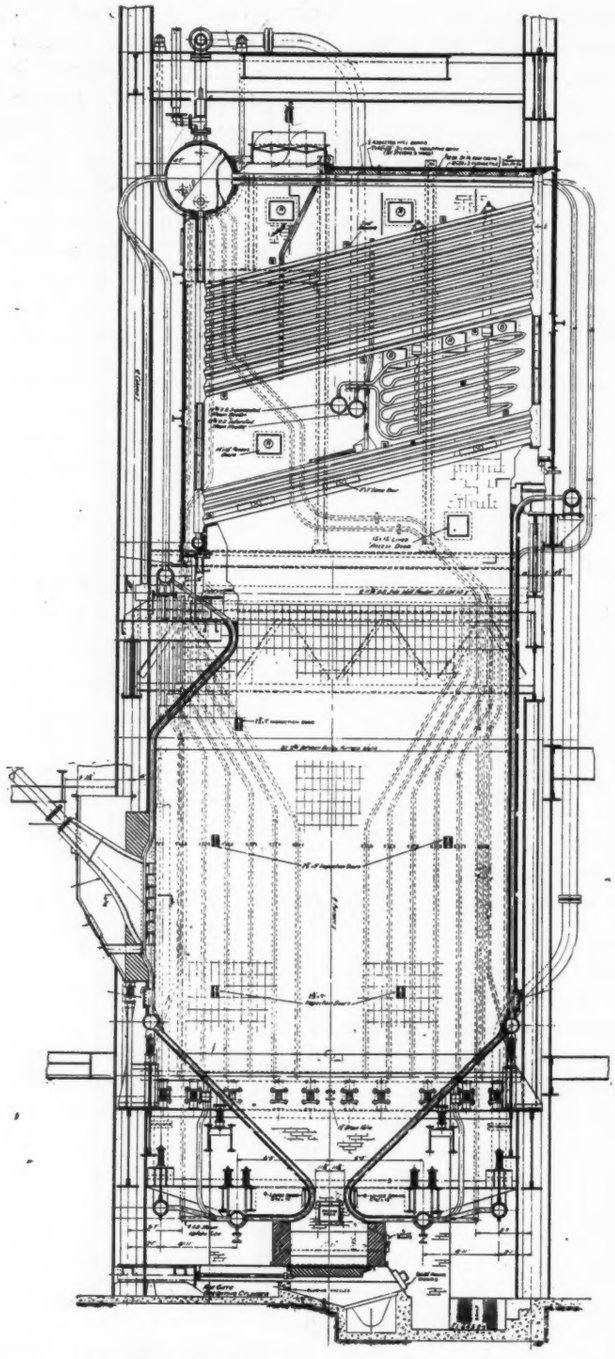


Fig. 3—Boilers No. 5 and No. 6, Toronto Station Ohio River Edison Company

surface below the temperature of ignition.

The arguments advanced for the bare tube wall are:

1. The furnace does not need to be hotter than the ignition point to produce satisfactory combustion.
2. The tube stresses due to exposure to the fire are not important.
3. The flame will be extinguished by contact with cold surface, but this can be avoided by not playing flame in cold surface; if flame does touch cold surface re-ignition will occur if there is furnace turbulence in the presence of other flame.
4. The top of the furnace at least must be cold to chill ash and avoid slagging the boiler tubes.
5. Slagging the ash from the ash-pit can be accomplished in a cold furnace by proper direction of flame.

Examination of the facts so far available discloses that in bare tube furnaces the combustion is as good, and the carbon loss as low, as in other furnaces. The combustion is chiefly influenced by firing equipment and operation, and apparently not by furnace cooling.

There are several installations at 1300 lb. to 1400 lb. now operating, and the bottom rows of tubes are not giving any especial trouble. These tubes work at higher rates than water-wall tubes since they receive a large amount of heat by convection as well as by radiation. The superheater tubes are working under still more severe conditions. There are one or two Benson boiler installations in Europe, at 3200 lb., in which no particular tube trouble is reported. It may be advanced that the bottom rows of boiler tubes are better protected than vertical wall tubes since the steam segregation is at the top, away from the fire. Actually, both wall tubes and bottom rows in the boiler are working at circulation rates much higher than the critical speed, so that the flow is fully turbulent, with no appreciable segregation of steam and water in either.

So far as flame extinction is concerned, Toronto boilers Nos. 1 to 4 give some interesting data. They were first equipped with long flame burners, forced hard, and water-walls with tubes clear of the wall. At ratings above 200 per cent they smoked badly, as the flame got behind the tubes, and the air mixture was poor until near the end of the flame, so that re-ignition was hindered. There was no furnace or burner turbulence.

Turbulent burners were installed, and the boilers are perfectly normal at all loads: same furnace.

Fourteenth Street and Kips Bay are two installations which might easily be expected to smoke, as they are both long-flame fired, with all cold furnace, and considerable impingement. They did smoke until the operators got used to handling the equipment, but now there could be no exception taken to the condition of stacks.

Liquid ash is tapped successfully from furnaces using either type of screen. One of the old boilers at Toronto with bare tube screens has been rearranged for slag tapping, and although the furnace was designed for dry ash removal, the operation is successful. The turbulent burners which replaced the long-flame burners are set so as to afford maxi-

mum heat to the liquid ash. Two covered tube wall furnaces next to this boiler (shown in Fig. 3) are arranged for tapping slag. These two boilers show

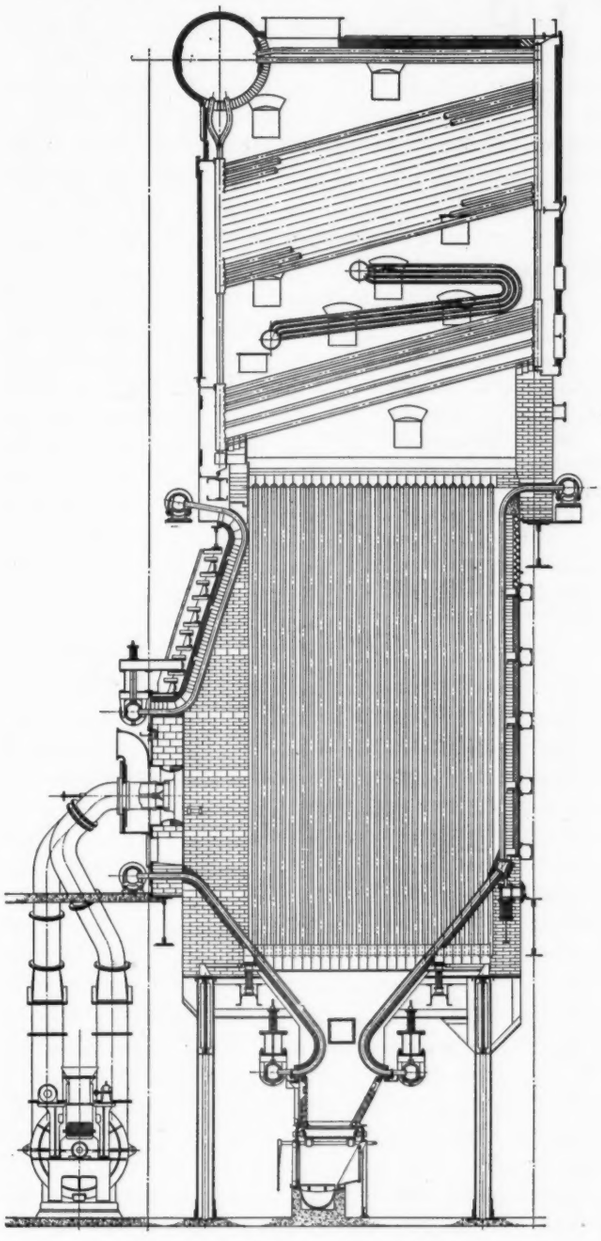


Fig. 4—Cahokia Station Installation

the effect of covered water-cooled walls upon condition of fly ash reaching the slag screen. The temperature at the superheater is approximately 500 degrees hotter than No. 1, with 10 per cent of bare tube, and cannot be forced to as high a rating without plastering the slag screen.

The main vulnerability of all water-cooled walls lies in taking away the heat. Two factors are involved; adequate quantity of water, and absence of scale. Nearly all tube troubles occurring with water-cooled walls are traceable to scale due to high concentration in feed water, or to a faulty circulation system. It is preferable to use condensate and evaporated make-up where possible. For those installations where it is not feasible to provide distilled feed, raw water should be treated to as low softness and total solids as possible, and continuous blow-down employed to keep the concentration down to 200 grains per gal., for hard-driven boilers, and 250 grains per gal. for moderate working.

The conclusions to be reached are now fairly evident:

1. There is every reason in favor of full-cooled furnaces.
2. The bare tube screen has the advantage on cost and effect upon the boiler.
3. Smoking will depend upon the burners, and operation; and only slightly upon impingement.
4. The short flame turbulent burner is generally most advantageous with all types of wall.
5. Covering is only desirable on screen surface in the ash-pit to protect tubes from abrasion; it is not essential, as slag will chill on the bare tubes and form a protective covering, both against abrasion and too great cooling.
6. If we can find a suitable refractory bottom, slag type furnaces would be better without any cooling.
7. If cooling surface is employed in the furnace it should be bare so as to earn as big a return as possible.

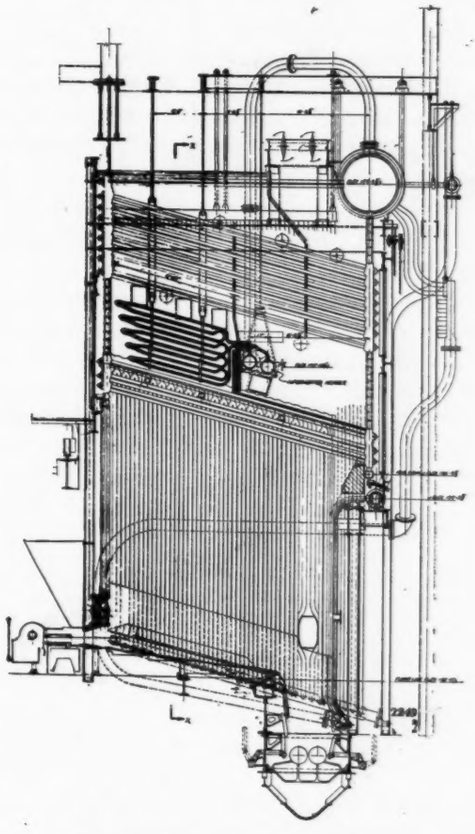


Fig. 5—Boiler setting, Kearny Station Public Service of New Jersey

The Standards *of* Steam Generation Move Up

By Carl Stripe, *Editor*

LITERALLY, combustion is a heat liberating process, and steam generation is a heat absorbing process. By a combination of the two, the potential energy of fuel is transformed into an available form of energy which can either be used in a prime mover to develop power, or employed in process work, or both.

Has progress in economic steam generation reached the zenith? All the plotted indications have already risen sharply, but has progress in the future been discounted? Efficiencies of 90 per cent apparently leave but little to work on. Steam temperatures in excess of 800 degrees Fahrenheit compel consideration of costly alloy steels. But how about further economies in the size of units? And what future opportunity for saving will there be by processing coal before burning it?

In the modern steam generating unit, the various pieces of equipment identified with these two processes are so closely interrelated that it is customary to consider them collectively as a co-ordinated group. The stoker or pulverized fuel system, the furnace, the boiler, the economizer, the superheater, the air preheater—are all correlated elements which comprise the complete steam generating unit.

A consideration of the status of steam generation should therefore include all these factors which contribute to the complete process.

The standards of steam plant performance have steadily improved due to the continued adoption of refinements in equipment and operation. Figure 1 shows the trend of overall boiler and furnace efficiency in the better steam generating plants of America for the fifty year period from 1880 to 1930. The dotted line indicates extrapolated values.

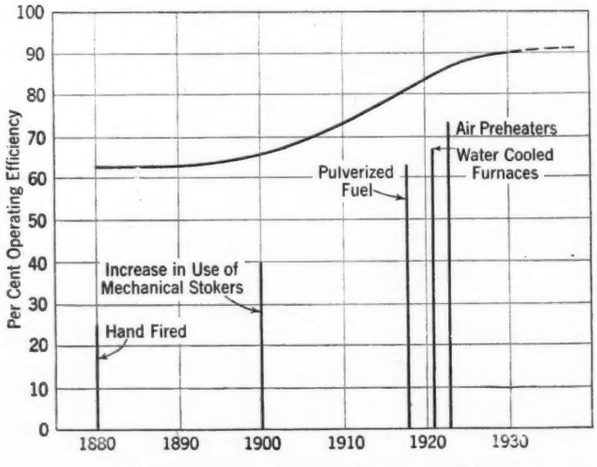


Fig. 1—Efficiencies from 1880 to 1930

Certain factors which have aided in improving the efficiency during this period are shown. The dates given are approximate and represent the general recognition and commercial adoption of new equipment and new methods to an extent which influenced the general trend in efficiency.

Certain other contributing factors are: increased size of units, higher standards of operation due to more intelligent supervision and the more general use of instruments, better initial design, which provided closer coordination of individual pieces of equipment comprising the complete steam generating unit.

This curve emphasizes two important conditions. First, the trend has been constantly upward, which indicates the ability and initiative of the manufacturers in making improved apparatus. By the introduction of new principles and the better application of old ones, they have made possible the continued improvement in steam generating efficiency.

This upward trend also evidences a willingness on the part of plant engineers and executives to investigate and adopt new equipment which offers possibilities for improving operating results. Progress is inevitable in any active field of endeavor, but it quickens when stimulated by a commercial incentive. The receptive attitude of the purchaser has served as the incentive and justification for the manufacturer to invest time and money in research and development work.

Second, the curve shows a decided tendency to flatten out in the immediate future despite the fact that in this field more progress has been made during the past decade than in any other similar period. This flattening of the curve indicates that the preventable losses incident to steam generation are approaching the economic minimum, and that the law of diminishing returns bars the way to further appreciable improvement in steam generation efficiencies.

The average efficiencies of all steam plants throughout the country are far below the values indicated in Figure 1, and a great opportunity exists to raise the performance standards in these average plants so that they will approach the maximum obtainable efficiencies as closely as is economically justified.

The curve, however, establishes fairly accurate

values for the top range of efficiencies that can be secured in commercial operation. Plants which today operate at these top efficiencies must therefore turn to other means if further economies are to be effected.

There still remain four judicious methods of improving overall steam plant economies—

1—the adoption of higher initial steam pressures
2—the adoption of higher steam temperatures
3—the adoption of boiler units having greater steaming capacity
4—the use of processed fuel

Figure 2 shows the general trend of maximum steam pressures in commercial use in this country for the half century from 1880 to 1930. During this

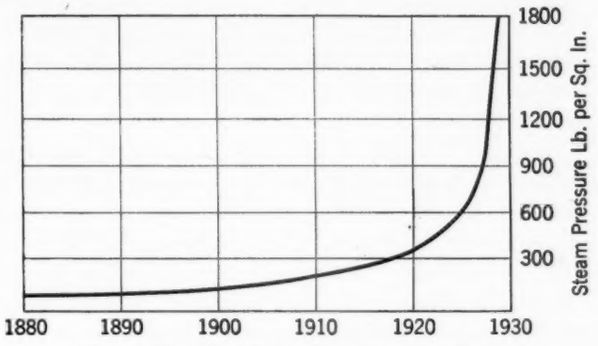


Fig. 2—Trend of Steam Pressure over 50 years

period there have been instances of high pressures applied in a limited way for special processing and test work, but these have been omitted from the chart as they are isolated cases and do not represent the trend of commercial development.

In forty-five years maximum pressures increased from 100 to 600 pounds per square inch. During the next four years the maximum pressure increased from 600 to 1800 pounds per square inch, which pressure has been adopted for the new high pressure plant of Philip Carey Manufacturing Company, Lockland, Ohio. This is the highest steam pressure yet adopted in America.

The usual justification for increased steam pressure has been the lower water rate and hence greater economy of the prime movers. This is strictly true in central station practice.

For industrial applications an additional reason for the adoption of high pressures has recently been recognized. The majority of industrial plants which require steam for process work have a parallel need for power. These two demands are usually closely related and increase or decrease with the rate of production in the manufacturing plant.

The steam pressures and temperatures for process work are frequently fixed by the requirements of the particular processing to be done.

The pressures and temperatures for power generation, however, are flexible factors which are limited only by the consideration—"how high a steam pressure and temperature are justified economically?"

This fact, combined with the relationship between process and power requirements, permits the use of a most efficient steam cycle by the adoption of an initial pressure sufficiently high to provide the necessary power when the prime mover is exhausting at a pressure high enough to meet the needs for process steam.

The engine or turbine thus functions as a reducing valve and shows high thermal efficiency, as only the difference in total heat of the steam at initial pressure and at exhaust pressure is chargeable to it.

The justification for higher steam pressures is largely a question of economics. The engineering problems involved are concerned principally with the utilization of high pressures—not the generation. The design of boilers for even the maximum pressure of 3200 pounds per square inch has presented no insurmountable problems. This pressure corresponds to the critical temperature of water, which is slightly above 700 deg. fahr., and well within the limits of safe practice for existing materials.

Steam pressures should therefore continue to increase as the economic advantages of high pressures become more widely recognized.

Figure 3 shows the general trend of maximum steam temperatures in commercial use in America for the fifty year period from 1880 to 1930.

There have been many isolated instances of high superheat, but the curve is limited to those applications which represent the trend of commercial development.

The advantages of high superheat and high steam temperatures are recognized. However, the curve shows a decided tendency to flatten out at a temper-

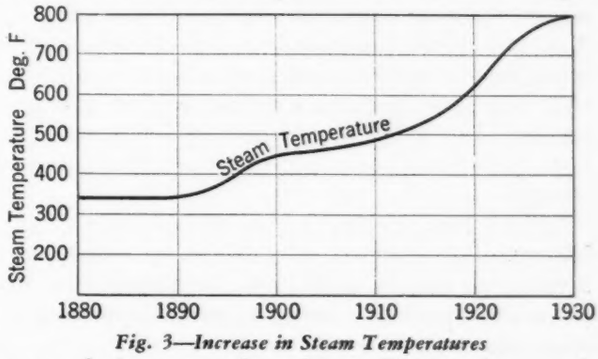


Fig. 3—Increase in Steam Temperatures

ature of about 800 deg. fahr. This is due to the limitations of existing materials and the pronounced tendency of carbon steels to creep at higher temperatures.

Steam temperatures have apparently reached the upper limit, for the present at least.

Suitable materials are rapidly being developed so that it will be possible to increase maximum steam temperatures to 1000 deg. fahr., or higher, and thus effect further economies.

Figure 4 shows the trend in American practice from 1880 to 1930, toward larger boilers and greater steaming capacity of individual units.

Two stoker-fired boilers, each having a capacity of 400,000 pounds of steam per hour, were recently

placed in operation at the Allegheny County Steam Heating Company, Pittsburgh. These units are believed to have the greatest steaming capacity ever secured from stoker firing. All capacities above 400,000 pounds shown on the curve are for pulverized fuel fired units. To date, the maximum developed capacity from a single unit is 660,000 pounds of steam per hour, secured at the Fordson plant of the Ford Motor Company. However, three units are

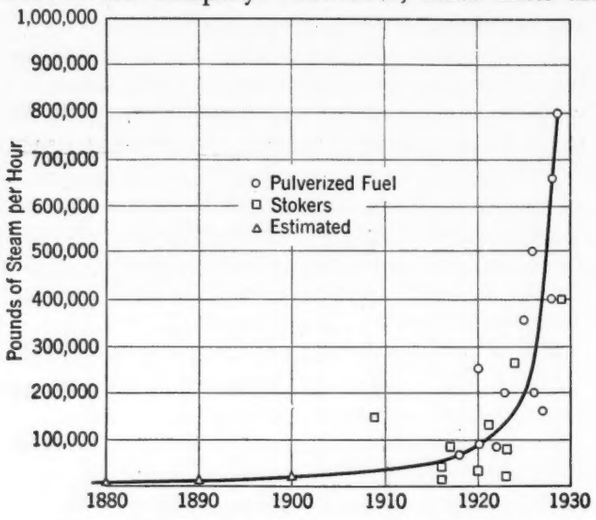


Fig. 4—Growth in size of Steam Generating Units

now in course of construction for the East River Station of New York Edison Company, each of which will deliver 800,000 pounds of steam per hour.

A number of factors contribute to the increased economy of operation which is possible with high capacity units. Initial investment costs are less for a given steam capacity. It is obvious that one 3000 h. p. boiler, complete with fuel burning equipment, would cost less than three 1000 h. p. units, and that one 1000 h. p. boiler, equipped to operate at 300 per cent rating, would cost less than three 1000 h. p. boilers each equipped to operate at 100 per cent rating.

Where land values are extremely high, as in Metropolitan districts, a considerable advantage in investment cost is gained by the adoption of high steaming capacities, due to the smaller ground area required.

It is equally obvious that the attendant labor costs for a given steam capacity will be less with the higher capacity units.

Radiation losses and banking losses can also be brought to a minimum with larger units and higher ratings.

Two factors are largely responsible for the tremendous increase in the steaming capacity of individual units installed during the past few years. The general adoption of pulverized fuel firing removed the limitations in fuel burning capacity which were imposed by mechanical stokers. The introduction of the all-metal, water-cooled furnace, removed the limitations of the refractory furnace.

Maximum steaming capacities will continue to increase, but a reference to Figure 4 will indicate that the increases in the future must come more slowly than those in the past few years.

In average American central station practice the cost of fuel represents about 75 per cent of the total steam cost. In our industrial steam plants it will average somewhat more—perhaps 80 per cent.

Any appreciable reduction in fuel costs would therefore insure an important reduction in total steam costs.

No economic condition exists which would tend to reduce the cost of raw fuels. On the contrary, the natural tendency is toward a steady increase in costs as demands increase and supplies diminish.

The low temperature carbonization of bituminous coal offers a logical means of reducing fuel costs by processing the raw coal and reclaiming the more valuable constituent elements before the fuel which remains is allocated to either domestic use or steam generation.

In order for the low temperature carbonization process actually and directly to lower the cost of steam in steam electric generating stations, the coke will have to be used as a fuel in boiler furnaces. It follows, therefore, that the cost of coke delivered to the boiler furnace must not be more than the cost of such coal as would ordinarily be used.

It must be pointed out that this is the direction in which development is at present tending.

The entire question of the economic production of gas, tar and oils, together with their derived products, is a separate, although parallel, development. The costs of production are fairly well understood. The markets are stable, and apparently adequate for a great deal of expansion. The price trend can be reasonably forecast.

These, and many other correlated problems, are now being worked out in the pioneer plants under practical competitive business conditions.

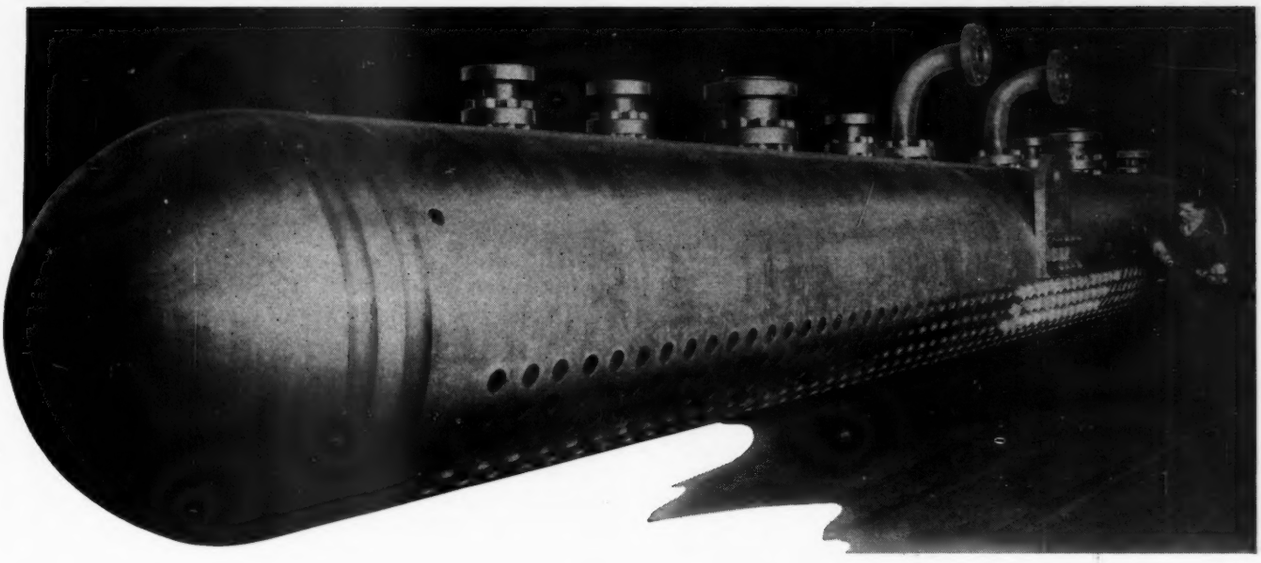
This, the newest development in the art of utilizing coal, has definitely joined in the march of coal economy, and reduction in the cost of making steam.

Service

SERVICE in business is not technical. It isn't even complicated. Yet it is the most powerful force in the world for building up good will.

This good will of a corporation may easily be valued in terms of millions of dollars, and even though this value is so intangible it is nevertheless very real.

Company policy is always aligned with service. The separate acts of service, however, will spring not so much from a stated policy as from the characters and habits of the personnel. Each individual, in his contacts with his fellows and with the public, will create his increment of good will according to his personality and training.



Special Design Problems In Vessels *for* High Pressures *and* Temperatures

By J. B. Crane
Combustion Engineering Corporation, New York

NUMEROUS laboratory tests have conclusively demonstrated that, above the strain hardening temperature of 550 deg. fahr., metals under stress tend to creep and permanently expand. As a result of these tests, there have been some attempts to ascribe definite values to the amount of creep as affected by temperature, stress and time. But while these values indicate clearly the trend of quantitative deformation, the tests are not sufficiently complete for using the values as accepted bases of design; we do not even know whether they are minimum, average or maximum values.

Laboratory tests cannot duplicate actual field conditions, nor are there any data from the field that will afford an accurate basis for the design of vessels for high pressures and temperatures. The use of the combination of pressure and temperature in steam boiler practice is too new to have yielded the information so urgently needed.

In the laboratory, as illustrated in Fig. 1, tests are made for 1,000 hours with definite strain and at definite temperatures. That is less than one-eighth of a year of continuous operation. A few tests have been made that extended over a period of about twelve months. Business economy demands boilers suitable not for 1,000 hours, or a year, but for a considerable number of years.

At 550 deg. Fahr., a new factor enters into the design of steam boiler drums. The metal tends to creep. Designers are working without complete data. This is a big problem, and Mr. Crane discusses it with the utmost frankness. He doesn't mince words, but refers to failure where failure is the correct term. Best of all, he shows a way to surmount the dangers involved.

The laboratory information is extremely valuable; there can be no gainsaying that, as the laboratory results are indicative of the quantity and direction of the values desired by the designer. However, field conditions impose on the steel or other metal used, many additional stresses that can scarcely be made the subject of laboratory tests. Many complex stresses are set up in an actual high pressure steam boiler unit by rolling tubes, alternate heating and cooling, high metal temperature due to scale, leaking baffles, beam action, and stresses caused by starting and stopping of units. The proper design of pressure vessels must adequately take into consideration all these actual conditions. It is necessary to face the fact that no accurate values are known for representing these conditions.

This is not so say, however, that pressure vessels designed today are unequal to the duty demanded of them. Boiler drums are actually in daily operation at over 550 deg. fahr. temperature, and over 1350 lb. per sq. in. steam pressure. They have not failed and are apparently designed with reasonable safety.

The method of design for pressure vessels, as provided by the A.S.M.E. boiler code for thick drums at higher pressures and temperatures, is open to question. The A.S.M.E. rules provide for the use of a factor of safety of 5 on the basis of the actual tensile

strength of the material at room temperature. In England and Europe, a factor of safety of 2½ is used, based on the yield point at drum temperature.

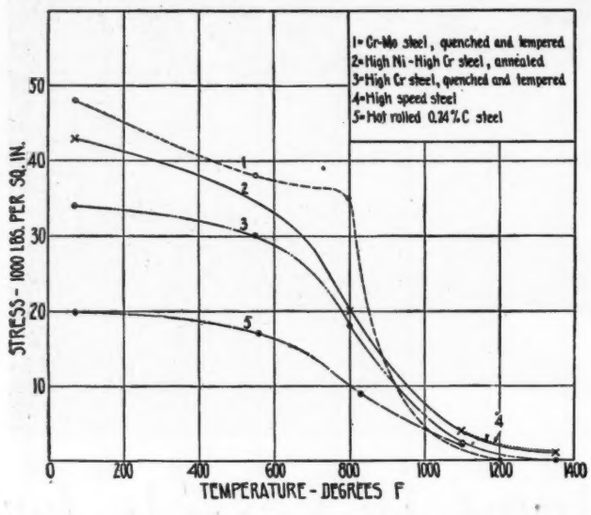


Fig. 1—Comparison of five steels on the basis of stress producing 0.1 per cent or less elongation in 1000 hours

Consider what is involved in the use of these methods. Mild carbon steel, as usually used in manufacturing steam boiler drums, has a tensile strength, at room temperature, of about 63,000 lb. per sq. in., and its yield point is about 29,900 lb. per sq. in. At 700 deg. fahr., the tensile strength remains at 63,000 lb., but the yield point drops to a value of about 18,500 lb. per sq. in. The allowable stress, under A.S.M.E. rules, would be $\frac{63{,}000}{5}$ = 12,600 lb. per sq. in., while under foreign rules it would be $\frac{18{,}500}{2.5}$ = 7400 lb. per sq. in.

If the carbon content is raised from the usual .20 to .40 per cent, there is a gain in tensile strength at room temperature to about 71,000 lb. per sq. in. and in the yield point to about 48,300 lb. But the increase in strength at 700 deg. fahr. is still more marked. At 700 deg. fahr. the tensile strength is 55,500 lb. and the yield point is 24,900 lb. per sq. in.

The curves of stresses at various temperatures in Fig. 1 are taken from Technical paper No. 362, issued by the United States Department of Commerce, Bureau of Standards. These are curves of actual test readings on various grades of steel. It is at once apparent that alloy steels, heat treated, have much higher strength than plain carbon steel. The conclusion that such steels must at once find their way into steam boiler construction is not warranted.

Such steels are entirely too expensive for competitive manufacturing. There is a limit to the size of billet that can be made, and from which the boiler drum is forged. Annealing of such a large article as a boiler drum is a tremendous problem. There is, furthermore, a whole region of unknown action for these steels, such as cracking under the strain of tube rolling.

The laboratory tests thus far made, indicate a decided trend toward permanent creep in metal subjected to temperatures above 550 deg. fahr. In view of the length of time necessary for securing complete data from the laboratory, it becomes evident that some method for keeping a permanent record of boilers in actual operation would be of inestimable value as a practical check on the present safety factors used in the design of boiler drums for pressures of 1,400 lb. per sq. in. and above.

The following is therefore offered as a method that would provide such information. On present drums, a place for measuring the diameter and circumference of drums would be shown by prick punch or other suitable markings. These would be roughly at one-third and two-thirds the length of the drum, which would be points of normal stress. On new drums, such places would be prepared while the drum was in course of manufacture, by turning smooth circumferential surfaces at points to be measured. During periods of operation, these surfaces should be protected by strips of metal underneath the drum insulation, so as to protect this surface from baked-on insulation or other dirt and thus make it relatively easy to clean before the periodic measurements were made. Such circumferential surfaces are shown at A and A1, Fig. 2.

Once a year the diameter from top to bottom and front to rear should be taken, and a record kept of such measurements.

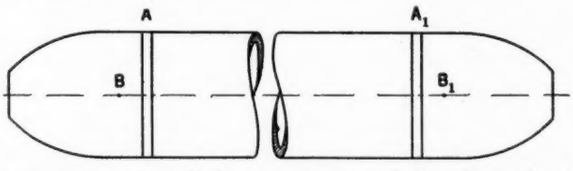


Fig. 2—Diagram of high pressure steam boiler drum showing turned bands and other places for measuring deformation

The growth in diameter will probably require micrometer fineness of readings in order properly to record it. Something in the nature of large calipers would seem to be the sort of instrument to use.

It is also advisable to check up accurately on the diameter of the drum by circumferential measurements, and since the change in measurement might be very small, and it is desirable to secure extremely accurate readings of the growth, an ordinary steel tape would seem too coarse a method for such measuring. To secure the desired accuracy, it would be advisable to use a measuring strip somewhat shorter than the circumference to be measured. Fig. 3 represents a special tape, having solid lugs on each end, to be used for this purpose. The over all length of the tape, end to end of the lugs, will be accurately known, of course, and micrometer measurements of the open space between lugs, when the special tape is applied to the clean circumferential surface of the drum, will give an exact measure for the record.

It is further suggested that a record be kept to show the deflection of the upper drums. This could be done by fixing permanent posts to the top of drums. There would be one in the center and one at each end directly in line with the hangers. A piano wire of a definite size and measured tension would be stretched between the two outside posts and the deflection of the center post taken with a micrometer caliper.

Fig. 3—Flexible tape or band with solid ends for measuring circumference of boiler drums

It is also suggested that prick punch marks be placed on the drum as shown at B and B1. These would be placed inside the furnace and about six inches from each side wall. Measurements would be made here each year to show if the drums tended to increase in length.

The temperature of the drum and measuring strip must be the same each time or the temperatures must be carefully recorded so that proper corrections can be made. Such measurements would be plotted and it is believed a curve something like that shown in Fig. 4 would be the result.

This curve is predicated on numerous laboratory experiments where the metal has been tested to destruction. Of course, in the laboratory, strains were imposed for the purpose of reaching the point of destruction within a comparatively short time. For actual drums in the field, the strains are figured so much lower that the time factor is very much increased. The point of this whole matter is that the time factor is unknown. It is therefore of the utmost importance that it be thoroughly studied in the field, in order safely to anticipate failure of drums by replacement.

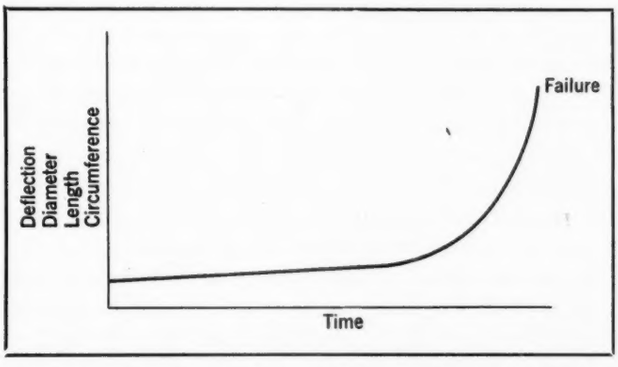


Fig. 4—Suggested record by plotting readings of deflection, diameter, length and circumference against time in years.

It is probable that when the time has elapsed up to the sharply rising point of the curve, the weakening of the metal due to creep would manifest itself by visible distortion sufficiently in advance of failure to constitute adequate warning. Piping might be thrown out of line, and ruptures and leaks would be the telltale sign. Tube holes might become oval and require reaming in order to keep tubes tight.

The suggested record is a far more rational way to watch the creep trend in the metal. By its use, there would be ample warning of the physical condition of the drum. The record would keep owners constantly reminded of the necessity for careful study of these drums. And not the least value of such records will be these necessary data for the designers of future vessels for similar purposes.

The word *failure* has a harsh sound to many of us. And yet it is an ordinary and frequent element of operating history of practically all equipment. When a boiler tube lets go, that is failure, and a common enough story in boiler plants. When a furnace wall melts down, when the metal of a stoker burns away, when a short circuit or ground occurs in a transmission line, when a tire blows out, when a steam engine requires reboring—these are all failures. They are all met by the method of frequent examination, and are anticipated wherever possible by replacement with a new part. In this matter of the high pressure boiler drum, the situation is identical. Such knowledge as we have, indicates a limited life, with the limit far enough away in years to be commercial, but at present unknown. Ordinary watchfulness, as outlined in this article, will anticipate failure with proper replacement.

47 Years Versus 27 Days

LAND values and building costs are important items in the fixed charges of steam plant operation.

The following comparison provides an impressive example of the progress which has been made in reducing these costs by the concentration of steam power in large units, operating at high ratings.

In 1882, forty-seven years ago, the first Heine boiler was built at St. Louis. This unit was rated at about 100 h.p.

Recently, New York Edison Company purchased three Combustion Steam Generating units, each capable of delivering 800,000 lb. of steam per hour.

One of the New York Edison units, operating at maximum rating, will be capable of delivering as much steam in less than twenty-seven full days as that first Heine boiler could have produced if it had been operated continually at full rating twelve hours per day, 300 days a year, for the entire forty-seven years since it was first built.

Or, to secure the same hourly capacity as one of the new 800,000 pound units—266 boilers, each the size of that first Heine unit, would be required.

As the capacity of prime movers has increased the size and rating of steam generating equipment has kept pace.

Incidentally, that first Heine Boiler is still in working condition and is open to public inspection at the St. Louis plant of the Heine Boiler Company.

Industrial Steam Generation Practice in Great Britain

A Review of the Present Situation

By DAVID BROWNLIE, *London*

SINCE the end of the War in 1918 there has been a distinct improvement both in the design and operation of industrial steam generation plants in Great Britain, although the progress is much slower than one would expect in view of the enormous attention that is being concentrated upon the steam user by sales organizations dealing with almost every conceivable type of plant and appliances for steam practice.

Incidentally, one of the most striking factors in the science of steam generation in this country is the multiplicity of scientific instruments of control, such as boiler feed meters, steam meters, combustion recorders and other automatic gas analyzing machines, pyrometers, and coal weighing machines that have been made available for the British steam user say during the past ten years, largely of both British and American manufacture, although German firms are now also beginning to be strongly represented.

A cross section of conditions in an industry or in a country is always interesting. The high points of power plant development in Great Britain are briefly summarized by Mr. Brownlie, who is a recognized authority on engineering practices in Europe, while at the same time he emphasizes the direction in which improvements will most likely continue. It is of special interest to note the differences between average practice in the United States and that obtaining in Great Britain.

It is very difficult to review the situation as regards steam boiler plant practice in Great Britain, or any other country, because in the first place civilization has not yet arrived at the stage of carrying out a proper engineering census, and this essential is lacking even in Germany, probably the most scientifically organized country in the world as regards fuel and power generally. I have been advocating the necessity of an engineering census for many years past, and such a proceeding will have to be carried out sooner or later.

Bearing in mind this absence of accurate and detailed statistical information on engineering and allied subjects, such as would be undertaken by the Government or other reputable authority, I have estimated in a number of publications the total amount of coal used for steam generation in Great Britain as 90,000,000 tons (2240 lb.) per annum, out of a total of 250,000,000 tons of coal mined per annum, and about 190,000,000 tons used in Great Britain itself as distinct from export and marine use. Further, the total amount of coal burned in Great Britain in electricity supply stations is approximately 8,000,000 tons per annum, leaving, therefore, 82,000,000 tons for industrial steam generation. Out of this figure I should estimate that about 50,000,000 tons is burned per annum in the internally fired cylindrical "Lancashire" boiler, with say 25,000,000 tons in many other varieties of boiler, such as the "Cornish" (internally fired single flue cylindrical), "Vertical," "Locomotive," "Marine," and other designs. It should be emphasized, however, that all these figures relate to stationary steam boiler plants and do not include the railways, which burn another 15,000,000 tons per annum.

Out of the 90,000,000 tons total for steam generation this leaves us with another 7,000,000 tons per annum burned under water-tube boilers for industrial steam generation.

I think this can be taken as a very fair representation of the conditions in Great Britain, and I may add that these estimates are based on nearly 20 years' experience in boiler plant work, and the personal inspection of roughly 2000 boiler plants in more than 50 different industries, including the complete scientific investigation of about 400 of these plants.

In the industrial field the key to the whole situation is, therefore, the "Lancashire" boiler, which can be taken as standard practice, generally with dimensions of say 30 ft. in length by 8 ft. 6 in. diameter, operating at pressures ranging from 100 to 220 lb. per square inch, and burning on the average 750 to 1100 lb. of coal per hour, with an evaporation that varies in practice from about 6.0 to 8.5 lb. of water per pound of coal. The representative British industrial plant is also fitted with cast iron feed-water economizers, raising the temperature of the inlet water, usually taken from the hot well of the engine at 100 deg. fahr. to 220 to 280 deg. fahr., while superheaters are now generally installed as well.

One of the most characteristic developments during the past few years has been the gradual increase in the use of scientific methods as regards mechanical induced draft in place of chimney draft, as well as the utilization of steam jet forced draft furnaces and the realization of the great economies that are to be obtained by using low grade fuels, with high furnace temperatures. For very many years Great Britain has been what may be termed essentially a "natural draft" country in boiler plant work, with chimneys of from 100 to 300 feet in height, and

unquestionably in many cases excellent results are obtained in this way, especially with the full complement of feed-water economizers and considerable reduction therefore of chimney gas temperature.

It is perhaps hardly necessary to emphasize that the average efficiency of steam generation throughout the world is deplorable. I have published a number of contributions on this subject in Great Britain, the gist of the matter being that the 90,000,000 tons of coal per annum is being burned at an average net efficiency of not more than 60 per cent, whereas if scientific methods were adopted universally, at least 20,000,000 tons of coal could be saved per annum; that is, nearly 25 per cent of the present coal bill. These figures may sound incredible, but they are the actual results of long extended investigations on steam boiler plants in Great Britain and the testing of 400 plants. Further, I am confident that the United States, Germany, France, or any other country is really no better in this respect, and that the world is burning something like 600,000,000 tons of coal per annum for steam generation at an efficiency that does not exceed 60 per cent, whereas the correct figure ought to be at least 75 per cent.

We are so used to reading of the remarkable results being obtained by large power stations that even the most expert fuel technologist is apt to be blinded to the fact that the largest proportion of the coal used in the world is not burned in modern power stations or even in the better-class of industrial plant, but under average conditions which in many cases can best be described as appalling, with overall steam generation efficiencies of actually less than 55 per cent.

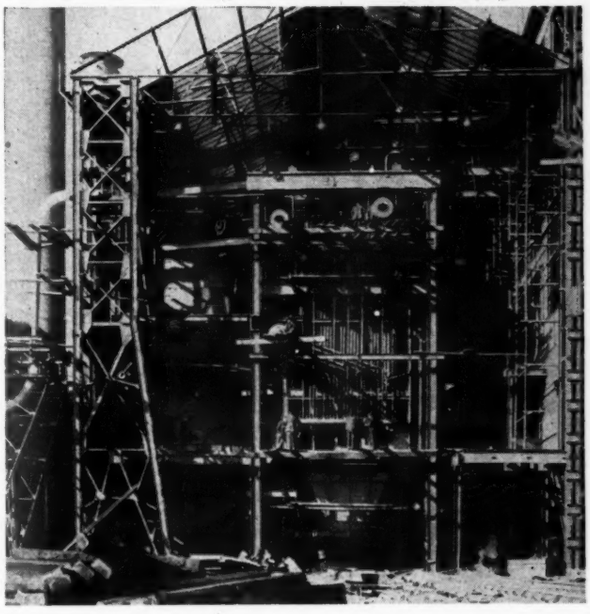


Fig. 1—Construction Photograph of New Plant Synthetic Ammonia and Nitrates, Ltd.

As regards feed-water economizers, Great Britain, curiously enough, has always adopted the feed-water economizer for industrial boiler plants. This subject has been very much more neglected in the United States where, on the other hand, the average steam user has adopted the superheater to a much greater extent than in Great Britain, for some mysterious reason.

We are now in the throes here of a highly interesting revolution in the feed-water economizer. Ever since about 1840, when Edward Green invented the cast iron economizer, this has been the standard practice as apart, of course, from very high pressures with water-tube boilers. Now the cast iron economizer is being menaced from two entirely different directions; firstly, the air preheater, and secondly, the steel tube or cast iron economizer with small diameter tubes and extended surfaces on the outside, having the water passing through them at very high velocity, and using steam jets to prevent the accumulation of ash and dirt on the outside of the extended surfaces.

So far, air preheating has not made much progress in conjunction with the "Lancashire" boiler, while hand firing still reigns supreme as regards the number of plants in operation, and certainly less than 40 per cent are equipped with mechanical stokers. With the "Lancashire" boiler having internal furnace tubes of not more than 3 ft. 2 in. diameter the employment of efficient mechanical stoking is not easy, especially as regards the cost of upkeep, quite different from the water-tube boiler, where practically unlimited grate area may be provided.

Also no progress has yet been made in Great Britain with pulverized fuel firing as applied to the internally flued boiler, at any rate on land, although during the past eighteen months great attention has been concentrated on the subject of pulverized fuel firing for the internal "Scotch" marine boiler. Here again the problem is extremely difficult, the main troubles being the length of the flame with pulverized fuel firing, and the melting of the ash. However, he would be a rash man indeed who would say that these problems will not be solved in the immediate future, and certainly this is already the case with the turbulent type of burner which gives a flame of less than ten feet in length.

Another highly interesting feature in British industrial steam generation practice is that the water-tube boiler is beginning to be used more and more, while also a few large industrial firms are now installing water-tube boilers at high pressures following upon the lastest power station practice. The most striking example in this connection is the plant now being erected for Synthetic Ammonia and Nitrates, Ltd., at Billingham-on-Tees, a subsidiary of Imperial Chemical Industries, Ltd., This is certainly the largest and most scientific high-pressure industrial installation in the world at the present moment, consisting of eight of the new "Lopulco" forged steel drum boilers to operate at 800 lb. per

square inch, with 840 deg. fahr. superheated steam temperature and a normal evaporation of 269,000 lb. of water per hour each, the whole equipment costing approximately £800,000 ($4,000,000). The installation includes the new turbulent type burner and other of the latest principles of pulverized fuel firing, with fin type steel tube, water-cooled furnace walls, air preheaters, and part of the hot air passed through the pulverizers to effect drying of the coal in the pulverizing mills. All the air—both "primary" and "secondary"—will go through the burners themselves, in contra-distinction to the usual methods, at any rate before 1929, of part of the air passed through the walls of the combustion chamber.

Another factor also in British industrial steam generation practice is the gradual improvement in the method of installing water softening plants, both of the lime and soda ash and the Base Exchange types. There are more than twenty different firms

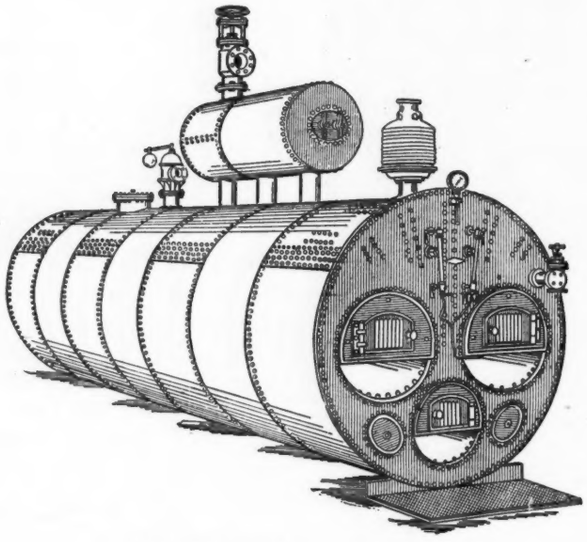


Fig. 2—Typical Lancashire Boiler

in Great Britain manufacturing equipment of this description, many of which complain that competition is now so keen in the sale of water softening equipment that there is hardly any profit to be made.

Finally, mention must also be made of two other important points closely associated with steam generation; that is, the use of back pressure types of steam engines or turbines, and the steam accumulator. For many years past there has been in Great Britain a great improvement as regards the number of back-pressure high-speed vertical steam engines that have been installed, whereby low-pressure steam is made available for "boiling" and general process work, thus avoiding the latent heat of steam loss in the condenser, while also a number of British engineering firms of high repute are specializing on the back-pressure steam turbine and also the back-pressure horizontal slow-speed reciprocating engine.

With regard to the steam accumulator, two designs of plant, the Ruths and the Kiesselbach, are now being pushed extensively in Great Britain, and although there are probably only about 30 installations yet at work, the steam user is having brought to his notice the advantages of the accumulator in conjunction with the operation of industrial steam boiler plants. The matter is, however, somewhat complicated, and the inherent drawback, of course, is the cost of the equipment, together with the difficulty of persuading the average factory owner to expend money on an accumulator instead of increasing his boiler plant.

False Economy

THE chief engineer of a large industrial company was not satisfied with the performance of his stokers. He thereupon called up the manufacturers of the equipment, and asked that an engineer be sent to inspect the stokers.

When the stoker engineer had checked up, he found the operating efficiency some 10 per cent lower than it should have been. One of the units was taken off the line, and an inspection of the grate revealed castings so badly made that they gave uneven distribution of air and inadequate motion of the parts. It was necessary to grind the castings and do considerable machine work to bring the operation up to standard.

A vigorous protest by the stoker engineer to his company about the poor castings drew a telegraphic reply that no repair orders had been received from that customer for over two years. He then ascertained that a local foundry had been supplying the parts at one cent per pound less than that charged by the stoker manufacturer.

Coal at this plant cost $5 per ton delivered to the stokers. The cost of repair parts averaged 5 cents per ton of coal burned. The 10 per cent reduction in plant efficiency was clearly caused by the poor quality of the locally made repair parts. In order to save about 1 cent in the cost of repair parts, the owner was taking a loss of about 50 cents.

A manufacturer of coal burning equipment, certain parts of which are destructible, has placed some of his reputation in the hands of the customer who uses the equipment. The customer counts on the cooperation of the manufacturer to service his installation; but, as this case shows, the customer may neglect his part of the cooperation. It is absolutely unfair for the customer to hold the manufacturer responsible for operation of equipment fitted with repair parts purchased from any other than the manufacturer.

Such local purchase of repair parts is not sound business. It violates the spirit of cooperation that should exist long after the original sale, and it is actually false economy in plain dollars and cents.

The Heat Balance Test *as a* Means *of* Obtaining Evaporative Efficiencies *of* Steam Generating Equipment

By B. J. Cross

Combustion Engineering Corporation, New York

THE fundamental operation for the determination of the efficiency of any energy converting apparatus is the division of the energy output by the energy input. This is the direct method and should always be employed when these two quantities can be accurately determined. For the determination of the efficiency of a boiler and furnace, this method entails the weighing of coal or other fuel delivered to the furnace and the weighing of the water evaporated in the boiler. The steam represents the operator's energy requirement and the coal represents the price he must pay for it. It is quite logical therefore to seek out these fundamental quantities.

Is there sufficient return from spending $500 to $2,000 for a steam plant test? What has become of fine accuracy in such a test when the heat balance requires 5 to 8 per cent in "radiation and unaccounted for" to balance? Mr. Cross has explained the factors of such a test. He has also examined the heat balance method of testing, and indicates its commercial value. The article is concise. Here is a complicated bit of combustion engineering handled in a style that makes it interesting. This paper was presented by Mr. Cross at the April meeting of the Metropolitan Section of A.S.M.E.

There is often however some difficulty in the direct weighing of the coal and water. Water especially is often difficult to weigh under the conditions that exist in the boiler room. In small plants where the water is fed cold to the boiler or economizer or to closed heaters it is usually not a difficult matter to install tanks ahead of the boiler feed pumps and weigh or measure all of the water fed to the boiler. In many cases, however, the weighing of water is very difficult and often practically impossible. The practice of feed water heating by stage bleeding of turbines has introduced many difficulties. The water cannot be handled in open tanks at temperatures approaching the boiling point. The water as it comes from the condensers does not represent the total amount fed to the boilers as a considerable quantity is by-passed through the heaters.

The greatest difficulty is in the quantities to be handled. Boilers that evaporate 300,000 to 500,000 pounds of water an hour are now fairly common and a few are operating or have been projected to operate at capacities up to 800,000 pounds per hour. Testing facilities have not kept pace with the development in size and capacities of boilers and it is improbable that any attempt will be made to weigh water to boilers at these rates. The expense of making complete evaporative tests on such large units would be very great and would usually be considered prohibitive.

The weighing of the coal used does not present so great a problem as does the water. In the first place its amount is only about 1/10 of that of the water. Even when it is to be used in powdered form, it can be weighed without difficulty, though special tanks or bins must be used. The greatest possibility for error is in judging the quantity of coal on the grates or in the pulverized coal bins at the start and end of the test. This error is reduced in per cent by making the test of long duration. However, if it is impractical or impossible to weigh the water, it is of little avail to weigh the coal. Whether or not the water can be weighed is usually the deciding question as to the possibility of making the evaporative test.

If it is not possible to weigh the water evaporated, the only alternative for the purpose of determining the efficiency of a steam generating unit is the heat balance method. This method consists of the measurement of losses and subtracting their sum from 100. It would more accurately be called the method of losses. It is the purpose of this paper to present a discussion of this method.

The heat balance is a part of all complete evaporative tests where fuel and water are weighed. The heat absorbed, as determined by the weight of water evaporated and its increase in heat content, plus the sum of all the losses, should equal 100 per cent. While all of the losses cannot be measured, those that can be measured can be determined quite accurately, while those that cannot be readily measured are small and are of the order of less than a tenth of a per cent. The item, "unaccounted for losses" in the heat balance, therefore, consists almost entirely of errors. These errors are commonly considered to lie in the measured losses. The following is a discussion of these losses and of the degree of precision with which they can be measured.

The losses that can be measured are as follows:

1. The loss due to the sensible heat above room temperature in the dry flue gases.
2. The loss due to steam in the flue gases. This steam comes from three sources: from evaporation of the moisture in the fuel; from the water formed when the hydrogen of the fuel combines with oxygen; and from the water vapor present in the air used for combustion.
3. The loss due to incomplete combustion of

carbon. This loss is evidenced by the presence of carbon monoxide in the flue gases.

4. The loss due to unburned solid carbon. This loss is represented by the carbon or combustible in the refuse from the ash pit and various settling chambers and the carbon in the refuse that is carried up the stack with the gases.
5. The loss due to the heat radiated from the surfaces of the unit. This loss cannot be directly measured but can be estimated and a figure set as a high limit.

Figure 1 shows a heat flow diagram of a steam generating unit. The quantities are all to scale. This diagram is to show the relative magnitude of the various quantities. The individual losses are small compared to the heat absorbed and a comparatively large error in their determination will have a proportionally small effect on the efficiency.

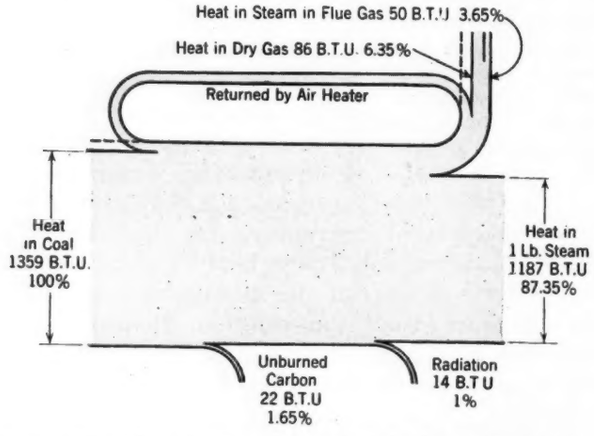

Heat in Steam in Flue Gas 50 B.T.U 3.65%
Heat in Dry Gas 86 B.T.U. 6.35%
Returned by Air Heater
Heat in Coal 1359 B.T.U. 100%
Heat in 1 Lb. Steam 1187 B.T.U 87.35%
Unburned Carbon 22 B.T.U 1.65%
Radiation 14 B.T U 1%

Fig. 1—Heat flow diagram illustrating the heat absorbed by a steam boiler, heat lost, and heat returned, in graphic relation to the heat available in one pound of fuel fired

The loss due to heat in the dry flue gases is the largest item of the heat balance. It is also the item that is susceptible to the largest error. The greatest precautions should, therefore, be used in its determination.

The formula for determining the weight of dry flue gases per pound of coal is usually written

$$\left[\frac{11\,CO_2 + 8\,O_2 + 7\,N_2 + 7\,CO}{3\,(CO_2 + CO)}\right] \times C_b$$

in which the various gases are expressed in per cent by volume and C_b is the carbon burned per pound coal.

This may be changed to

$$\left[\frac{4\,CO_2 + O_2 + 7\,(CO_2 + O_2 + N_2 + CO)}{3\,(CO_2 + CO)}\right] \times C_b$$

But as $(CO_2 + O_2 + N_2 + CO)$ constitute 100 per cent the formula in its simplest form becomes

$$\left[\frac{4\,CO_2 + O_2 + 700}{3\,(CO_2 + CO)}\right] \times C_b$$

The entire expression for the heat lost in the dry gases is

$$\left[\frac{4\,CO_2 + O_2 + 700}{3\,(CO_2 + CO)}\right] \times C_b \times \left[.24\,(t_2 - t_1)\right]$$

The items that are measured are, CO_2, O_2 and CO in per cent by volume, t_2 the flue gas temperature and t_1 the air temperature. C_b the carbon burned is obtained by subtracting the unburned carbon per pound of coal from the carbon as reported by ultimate analysis.

The most important measurements in the determination of the dry gas loss are the CO_2 and flue gas temperature. The oxygen and CO are small quantities and considerable error in their determination causes only a small error in the result. C_b, the carbon burned will vary only slightly with an error in the unconsumed carbon. It is improbable that any considerable error will be made in room air temperature.

The possible error in measuring CO_2 is influenced almost entirely by the location of the sampler. Once the sample is in the orsat, its analysis can be made with an accuracy of plus or minus .2 of a per cent. The difficulty lies in obtaining a true sample. A great many devices have been tried in the attempt to obtain a single sample that is representative of the composition of the gas. Probably the best way is to use simple open end pipes, taking as many samples in as many locations as the resources at hand permit. In wide settings as many as 6 samplers distributed across the setting may be necessary. A preliminary traverse of the breeching may be made and the variation in composition of the gases determined. The greater the variation the larger the number of sampling points will be necessary. In modern units where often both economizers and air heaters are employed, the gases are apt to be rather thoroughly mixed by the time they leave the system and the sampling thereby simplified. Air leakage between the various units increases the difficulty of sampling and should be kept at a minimum.

The error in the per cent CO_2 due to sampling and analysis should with proper care not exceed half of a per cent.

As in the sampling and analysis of gases, the possible error in the determination of temperature of the flue gases is due almost entirely to the location of the instrument used. The solution similarly is to use as many points as possible. A temperature traverse may be made and the number of points to be used and their locations thus determined. The use of thermocouples in this measurement permits a large number of temperature measurements to be made in a section of the breeching with a minimum of effort and expense. In a breeching for example, of 5 feet by 15 feet, 5 couples may be located at 3 foot intervals. Each couple may then be moved to 5 positions. Twenty-five readings can thus be made

at as many points in the section. If a little care has been taken in wiring the couples to a convenient switch, these twenty-five measurements can be made

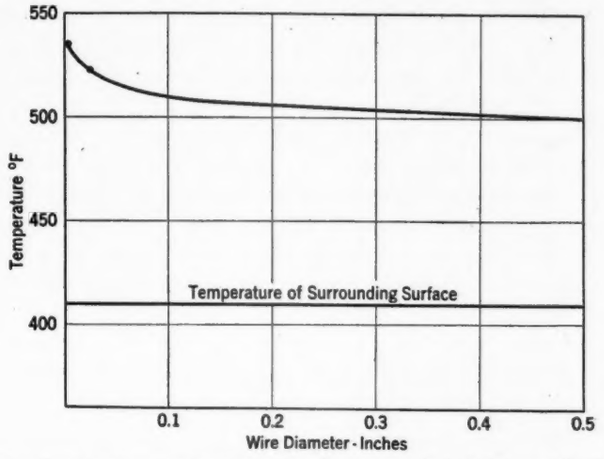


Fig. 2—Junction temperature of a thermocouple is influenced both by the size of wires used and by the temperature of surrounding surfaces

in not more than five minutes. A potentiometer should preferably be used in these measurements as there is then no error due to the resistance of the leads.

The thermocouple used for measurement of gas temperature should be made of wire as small in diameter as possible, consistent with durability. Theoretically in a stream of hot gas, inclosed by walls at a lower temperature than the gas, the junction of the couple can never reach the gas temperature. It is receiving heat from the gases and radiating heat to the walls of the duct. The temperature it indicates is therefore an equilibrium temperature and lies somewhere between the gas temperature and the wall temperature. The smaller the diameter of the wire the closer will be the indicated temperature to the true temperature.

Figure 2 shows the effect of wire diameter on the indicated temperature. This figure is taken from Bulletin 145 of the U. S. Bureau of Mines and is based on experimental data by Kreisinger and Barkley. In practice No. 22 B & S gage wire which is .025 inch in diameter has been found to be well suited. It is large enough to be fairly durable and is not too large to cause a serious error due to radiation. In gas ducts, the walls of which are insulated and where the gas velocity is fairly high, the error due to radiation should not be large. In boiler settings where the gas velocities are low and the couple can "see" the comparatively cooler boiler surfaces the radiation error may be considerable.

The junction of a thermocouple is best made by welding. Copper constantan couples can be welded in an ordinary bunsen burner or even in the flame of a small gasoline blow torch. Iron-constantan couples require a higher temperature and an oxygen-gas flame or an electric arc must be used. The wires should be butt welded, the junction being but little if any larger in diameter than the wire. Figure 3 shows some examples of good and bad thermocouple junctions. The hot junction of a couple is shown at (a). The wire of the couple should project well beyond its protection tube. The error due to the conduction of heat along the wire is thus minimized. A good butt weld is shown at (b). (c) shows a couple with a bead, the wire has been held in the flame too long and the surface tension of the molten metal has drawn the melted metal from the ends of the wires causing the thin sections near the bead. Such a weld is fragile and in addition there is apt to be a large error due to radiation. At (d) is shown a couple with too short an exposure to the gas. The outside supporting pipe and the insulation are always at a lower temperature than the wire of the couple and heat is conducted from the wire. All

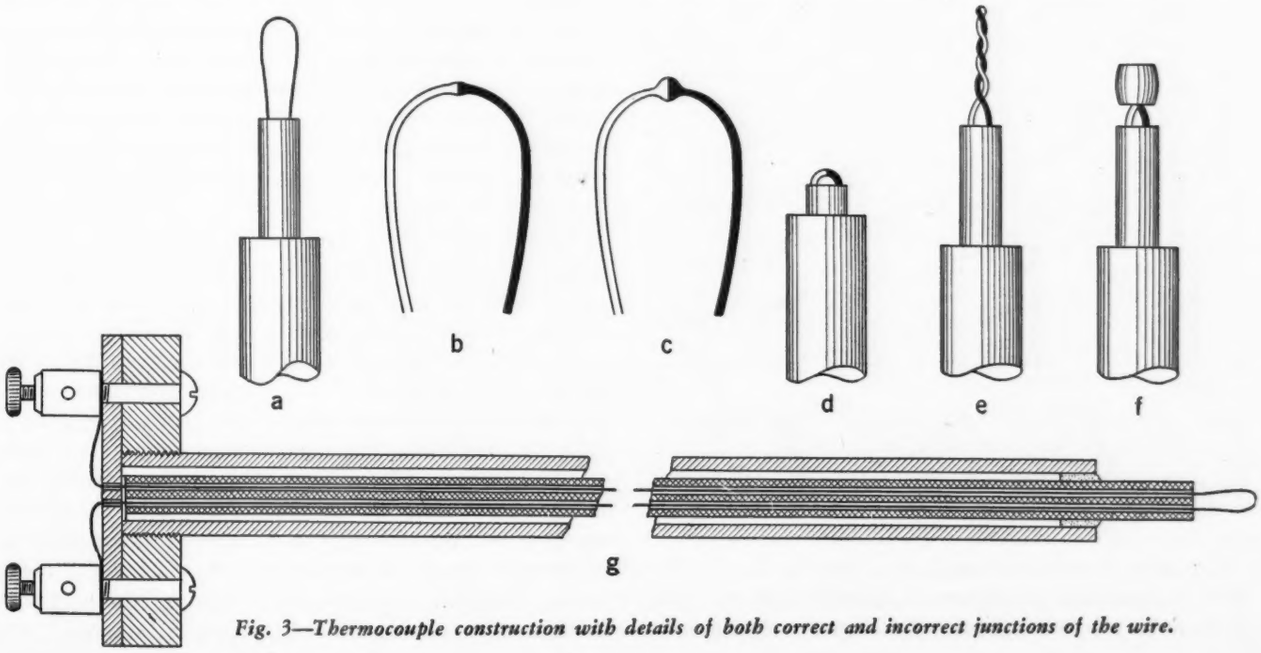


Fig. 3—Thermocouple construction with details of both correct and incorrect junctions of the wire.

that can be said in favor of (e) and (f) is that they are easy to make. The greatest advantage in the use of a thermocouple in measuring flue gas temperatures lies in the small mass of the active part of the instrument. In examples (e) and (f) this advantage is sacrificed.

A completed couple is shown at (g). It consists of a 1/4 inch iron pipe which supports the wire in a suitable insulation. This insulation may consist of porcelain or glass tubing. The head holding the binding posts may be made of fibre or wood. The cost of such a couple should not exceed $1.00, labor included, and the wire can be renewed at the cost of a few cents.

A good portable potentiometer should be part of the equipment of the boiler room. Thermocouples can replace mercury thermometers in most temperature measurements. While the first cost of the potentiometer is higher than that of the thermometers, the upkeep is apt to be considerably lower. Bulletin 145 of the U. S. Bureau of Mines is recommended as a text on the use of thermocouples.

The calibration error of a couple over the range of temperatures found in flue gases should not exceed 2 or 3 degrees. The largest chance for error is due to the location of the couple and the radiation of heat to cooler surrounding surfaces. In ducts, the walls of which are well insulated, the temperature of the walls will not be far below that of the gases. The error due to radiation should not exceed 10° F. The combined error due to radiation and location should not exceed 15° F.

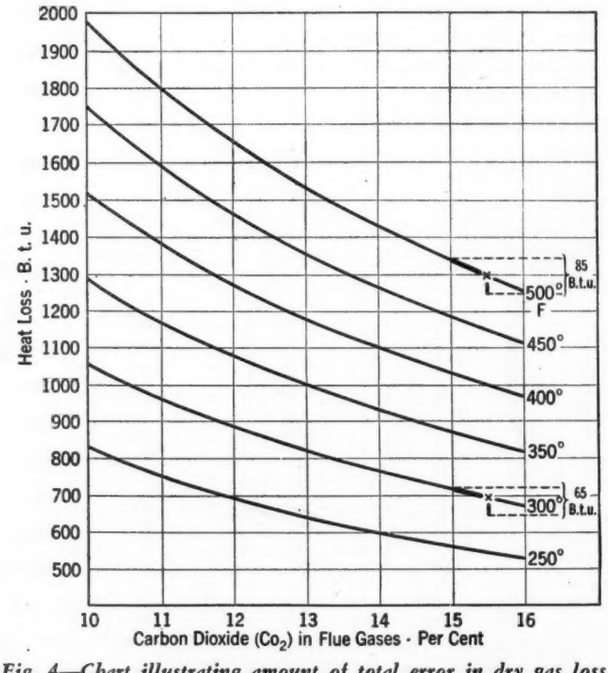


Fig. 4—Chart illustrating amount of total error in dry gas loss, due to combined error of one-half per cent of CO_2 and 15 deg. of exit gas temperature

Figure 4 shows the loss due to heat in the dry flue gases at various temperatures plotted against CO_2. Thus at 15 per cent CO_2 and 500 degrees temperature, an error of ½ per cent in CO_2 and 15 degrees in temperature will cause an error of 85 B. t. u. or 6 per cent of the total quantity of heat lost. But this represents an error of only 0.5 per cent in the efficiency. At a temperature of 300 degrees and 15 per cent CO_2, the same errors in measurement will cause an error of 65 B. t. u., or 9 per cent of the total loss. But again this represents an error of only 0.55 per cent in the efficiency.

The loss second in importance in size is that due to moisture in the flue gases. This moisture comes from three sources, the moisture in the fuel, the water vapor present in the air used for combustion, and the moisture formed by the combustion of hydrogen in the fuel.

Where the moisture (W_m) must first be evaporated as is the case with the moisture in the fuel and that formed by burning hydrogen, the loss is equal to $W_m = [1050 + .48 (t_2 - t_1)]$. As the latent heat of evaporation is large in comparison with the second term, the loss is almost constant. It would take a considerable error in t_2, the flue gas temperature, to appreciably affect the final result. An error of 15 degrees in the temperature affects the efficiency about 1/4 per cent.

The equation for the heat in steam in flue gases is sometimes written

$$\text{loss} = W_m [(212 - t) + 970.4 + .48 (t_2 - 212)]$$

This implies that the moisture is evaporated at a temperature of 212 and superheated to the temperature of the stack gases. Actually the water is evaporated not at atmospheric pressure but at its own partial pressure. A more nearly correct expression which also has the advantage of being simpler is,

$$\text{loss} = W_m [1050 + .48 (t_2 - t_1)]$$

The actual difference in results by the two methods is however, small.

As the loss due to moisture in the air used for combustion is very small, usually less than .1 per cent, any error in its determination need not be considered.

The loss due to unburned carbon is difficult to measure. If this loss occurred entirely in the ash pit, its determination, while apt to be rather laborious, would be comparatively simple. A considerable part of the unburned carbon however passes out of the stack with the gases. This is true both of stokers and powdered coal fired furnaces. The ash pit loss can be determined by the weight of refuse and its analysis. The loss of carbon in the stack gases can be determined with a fair degree of accuracy by aspirating a known weight of gases through a collector and filter. Such a device is shown in Figure 5. The purpose of the flow measurement by means of the orifice is to obtain the correct velocity at the sampler intake and also to obtain a quantitative measure of the total amount of refuse carried up the stack. Sampler area over total area of the duct is a fraction representing the proportion of the total gases

that must be drawn through the apparatus. The assumption is made that the velocity at the point of sampling is the average velocity in the duct. The

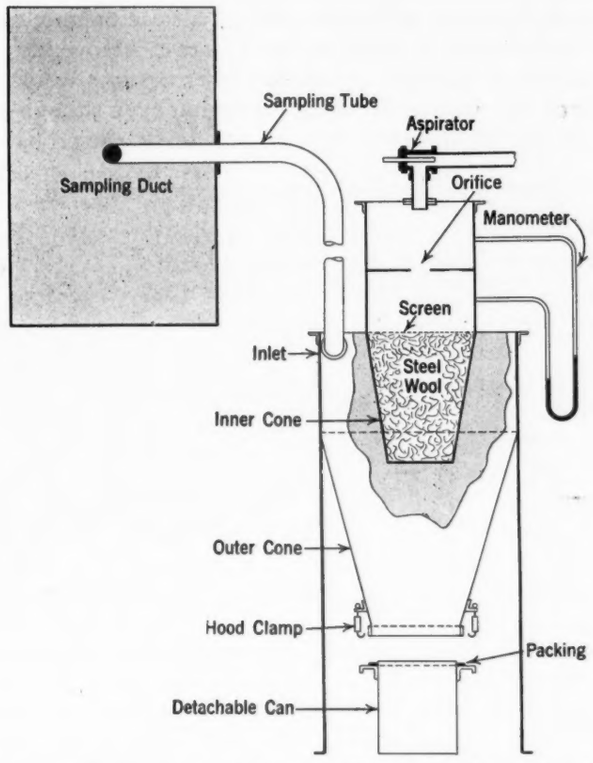


Fig. 5—Arrangement of device for collecting samples of dust in flue gas for determining carbon loss to chimney

error in quantity of refuse so determined may be as great as 10 per cent. The error in quality, i. e., carbon content, is due chiefly to the loss of fine particles and is usually on the high side. The combined error of sampling in quantity of refuse and quality of the sample obtained should not exceed 20 per cent. If the total loss due to unburned solid carbon is 1½ per cent, the maximum error in the efficiency would then be .3 per cent.

The error in the chemical analysis of the refuse is probably on the high side. The method for determining the combustible consists of burning the sample in a muffle furnace and calling the loss in weight carbon which is assumed to have a heat value of 14,600 B. t. u. per pound. Actual calorimetric determinations of the combustible have shown a heat value averaging about 13,800 B. t. u. per pound. The combustible as determined by the loss in weight on burning is apparently not pure carbon.

The loss due to radiation of heat from the boiler setting cannot be directly measured. The rate of radiation from such surfaces has, however, been the subject of much study and is of the order of about 250 B. t. u. per hour per square foot. Boiler and furnace walls are usually well insulated and there are few parts of a setting where the hand cannot be comfortably held.

As in most plants boilers are set in battery or adjacent, the radiation amounts in part to a mutual exchange and the loss is reduced. The rate of 250 B. t. u. per square foot per hour can be safely said to be a maximum figure. The surface exposed need not be accurately measured but only approximated.

The actual loss due to radiation is practically constant regardless of rating. It can be estimated for normal rating of the boiler and the loss at any rating may then be computed by dividing by the per cent rating. The per cent loss due to radiation will thus vary considerably with rating. At moderate ratings it will be in the neighborhood of 1.0 per cent. The error in computing this loss will not exceed 25 per cent of the loss and would cause an error of .25 per cent in efficiency.

The error in the heat value of the fuel may result from two causes: the sampling of the coal at the plant and in the analysis of the sample in the laboratory. The error of sampling, even when the most careful methods are used, may be considerable. If the coal is moist, as is often the case, the time consumed in sampling must be kept at a minimum in order that the loss of moisture be kept low. On the other hand, time is required to reduce the sample in size and to mix it thoroughly so that the samples taken may be representative. The best way out of this dilemma is to take a separate sample for the moisture content—and another sample for the analysis and heat value determination. Investigations are now in progress to determine the accuracy with which coal may be sampled, the preliminary results of which indicate that an error of 150 to 200 B. t. u. may be expected. The error of analysis of coal is smaller. A chemist is expected to check his own determination within 40 to 50 B. t. u. Different laboratories should check within 75 B. t. u. The combined error due to sampling and analysis may easily be 200 B. t. u.

For the purpose of a heat balance test an error of 200 B. t. u. in the heat value of the fuel, fortunately is not serious. The equation for efficiency by the heat balance method is

$$\frac{\text{B. t. u. of coal} - \text{B. t. u. of losses}}{\text{B. t. u. of coal}}$$

As the term B. t. u. of coal appears in both the numerator and denominator the error is largely compensated.

In a comparison of heat balances of tests made 10 or 15 years ago with those made more recently, one of the noticeable differences is in the CO reported in the flue gases. Where it was once common to report percentages of CO from 0.5 to 1.0, in the more recent tests this item is usually zero. This difference is due to the increase in size of combustion chambers and the use of air over the fuel bed. As the amount of CO is small—usually it is unmeasurable—and the same per cent error in its determination applies as for CO_2 determination, the error in the determination of this loss can be safely neglected.

If radiation has been accounted for by the method previously described, the unaccounted for losses should consist only of the undetermined items of the gas analysis and sensible heat in refuse. The undetermined constituents of the stable gases consist of unburned hydrogen and hydrocarbons. The loss due to these constituents can almost invariably be neglected because they usually exist only in traces.

The amount of heat lost due to the sensible heat in the ash and refuse is usually very small, although if ashes are rejected from the furnace in molten state the loss may be appreciable. However, in this special case the loss may be readily calculated.

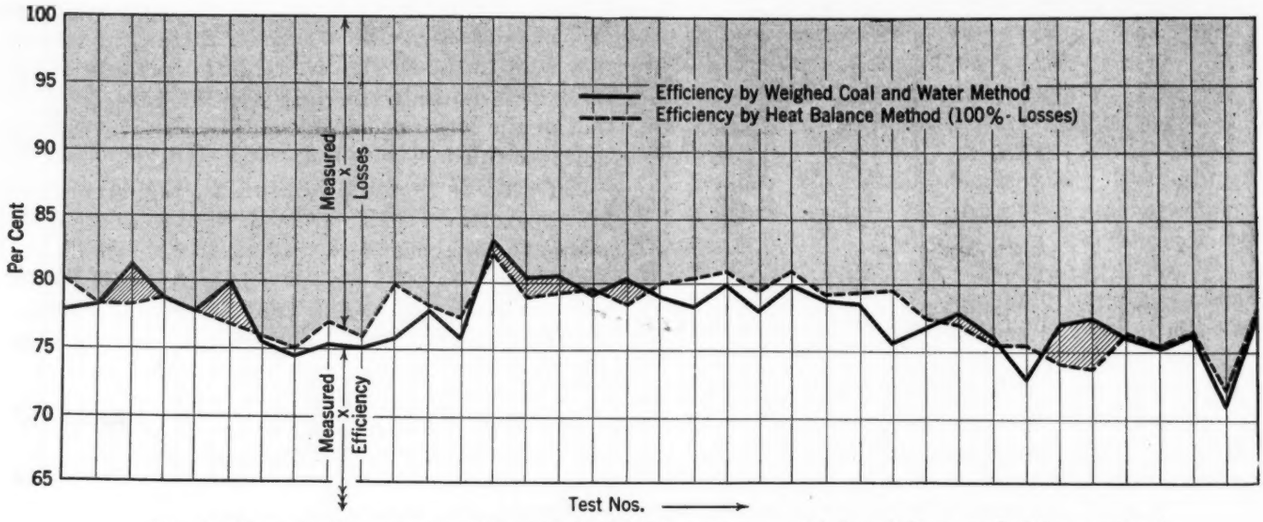


Fig. 6—Chart showing comparison of weighed coal and water tests with heat balance method for a series of actual stoker tests

The possible errors of the items of the heat balance as discussed in the preceding paragraphs are to be considered as the maximum errors when all reasonable precautions have been taken to obtain accurate measurements of the factors involved. These errors are for the greater part accidental rather than constant. They may be plus or minus in direction and just as apt to be compensating as additive. Considered under the most unfavorable circumstances where they will be additive, the total error in the sum of the losses will be the sum of the errors of the individual losses. The total maximum error in obtaining the efficiency of a boiler and furnace by the heat balance method may be determined therefore by summing up the individual errors. Thus the total error of a carefully made heat balance efficiency test will be as follows:

1. Error in dry gas loss	0.5 per cent
2. Error in loss from steam in flue gases	0.1 per cent
3. Error in loss in incomplete combustion	0.4 per cent
4. Error in radiation loss	0.2 per cent
5. Error due to sampling and analysis of fuel	0.2 per cent
Total error in efficiency . .	1.4 per cent

If we add .1 per cent for the unmeasured losses the total possible error in efficiency by this method is 1.5 cent.

To those who like to report the results of a boiler test to the second decimal place, the admission of a possible error of 1.5 per cent in a heat balance test would seem to condemn such a test. However, if we investigate the possibility of errors in a weighed coal and water test we will find that even though all measurements are made with great care, the probable error of such a test will not be greatly different from that of the heat balance test. Unlike the efficiency as determined from the heat balance the efficiency as determined from a weighed coal and water test is greatly affected by an error in the heat value of the fuel. An error of 150 B. t. u. in the heat value will cause an error in efficiency of over 1 per cent.

The heat absorbed per pound of steam evaporated is determined by the temperature of the feed water and the temperature and pressure of superheated steam. The temperature of the feed water can be determined to within 2° F. and that of the superheated steam to within 5° F. The combined error of these two temperatures is .4 per cent. Even neglecting the possibility of error in the weighing of

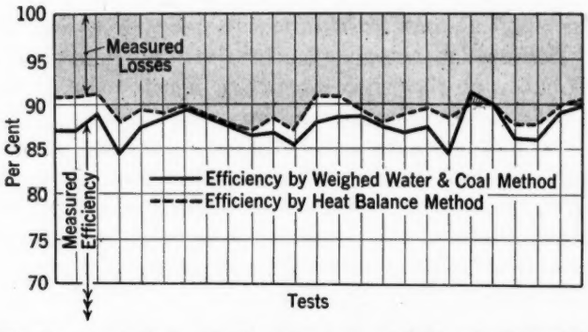


Fig. 7—Comparison of the two test methods of determining efficiency. Chart shows results for 25 tests on a pulverized coal fired boiler

coal and water we see that the error of a weighed coal and water test may easily be 1½ per cent.

A comparison between the efficiency as obtained from weighed water and coal and efficiency as determined by heat balance is shown in Figures 6 and 7. These figures show graphically the results of a series of complete tests on a stoker fired boiler and pulverized coal fired boiler respectively. In these figures the efficiency by weighed water and coal is plotted upward from the zero ordinate; the losses are plotted downward from the 100 per cent line. The amount by which the sum of the total losses do not meet the efficiency as obtained by the evaporative tests or the amount by which they overlap represents what is usually called the unaccounted for losses but what should more correctly be called the error of the tests.

It will be seen that the maximum error in these diagrams is 3 per cent. As it has been shown that the maximum probable error of both the heat balance test and weighed water and coal test is in the neighborhood of 1½ per cent, a combined error of 3 per cent is possible.

It has not been the purpose of this paper to depreciate the weighed coal and water test. Tests should be made by this method whenever possible. Such tests should also be checked by means of a heat balance whenever possible. This paper has attempted to show that the efficiency as determined by the heat balance method or by the method of losses as it would more accurately be called, should have equal value with an efficiency as obtained by a weighed coal and water test.

The Stuff from which Engineering Progress is Made

By R. C. Denny

THE man in dungarees used to scoff at the white collar engineer. Could a man learn to run an engine by calculus? Could the right kind of packing be picked out of a book? A bit of arithmetic, and some knowledge of strength of materials of course were necessary to get a first class operator's license, but how about the six or eight years of practical operating? They didn't teach that in any school. No; the men who counted had served their time in the shops, or operated for many years, as an essential element of their rise in the engineering world. They were practical men.

This was the old system under which engineering progress for many years was steady, but slow. And these same practical engineers have long been the backbone of our engineering advance. In fact, it is doubtful if many of our brilliant achievements of recent years could have been developed nearly so rapidly without the cooperation of the practical men.

These men live close to the machines. They follow the actual functioning of the machines with minds and hands alert to every phase of its operation. Their thoughts are busy with what is actually happening within the apparatus. They are familiar with every minute change of operation and change in product, and from this close and practical contact they evolve changes and suggest improvements. They are continually adding to the sum total of engineering. For the most part, their work is done in obscurity, and their multitude of successes bring little praise, and still less fame.

Now, there is another method of engineering progress. Men are highly trained in technical schools, given just enough practical contact to serve the general purpose, and are turned loose in technical research crews. They are the same breed as the older, practical men, but they work in a different environment. Considerable of their work is done in the region of scientific imagination. Their tools are technical education, the magic slide rule, and reams of paper. In their brains a new machine takes shape, utilizing a new principle, its problems carefully catalogued, its components deftly coordinated, its limitations well recognized. By study, by research, by consultation, they rough out its outlines and transfer the thought to paper. Every calculable phase is figured and checked.

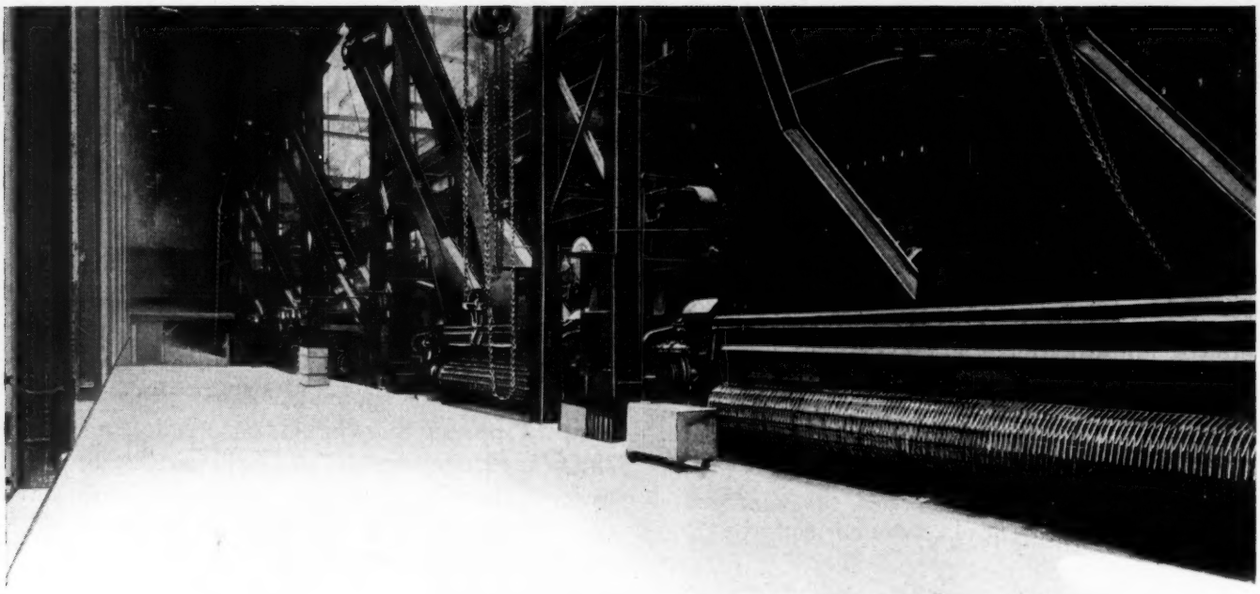
Yet these men are well aware of the gap between theoretical and practical. They are modest by virtue of their great knowledge, and they will claim only for their created machine that its performance will be thus, and so provided the whole assembly proves completely practical. Usually they hit the button.

Progress with these men is speedy. An entirely new area of engineering endeavor can be and is penetrated by their method.

But behind both of these forces of engineering progress is the business man. Our social structure requires that improvements must be commercial. What is improved or invented must be salable, at a profit. Before money is spent for wages and for construction there must be a reasonable vision of commerce with profit.

This is the business function. This is where the executive must take a chance. He must have the vision, either his own or another's; he must calculate his risk and initiate the expenditures; and then he must follow through, often enough in the face of initial failure to that commercial success which he originally foresaw.

Here, then, is the story of the steam boiler, of the steam turbine, of stokers and pulverized fuel, of the modern power plant, and still more recently, the story of low temperature distillation.



Saving Midwestern Dollars *by* Matching Fuel Burning Equipment *to* Available Coal

By T. A. Marsh

Combustion Engineering Corporation, Chicago

NOBODY wants to waste money. Economy in spending is the result of a thorough appreciation of the values involved. The wisest expenditure may not be for the cheapest coal burning equipment, nor yet for the most expensive. In order not to waste money in the selection of such equipment, the buyer will examine with the utmost care every important relation between the fuel, the equipment, and the character of plant. Some of these relations have undergone rather rapid change in the past few years; and new ones have made their appearance.

Nothing could be further from fact than to assume that a standardized boiler, stoker and furnace would, equally well, burn any kind of coal. Instead of making a start at the analysis of the plant equipment problem by considering standardized combinations, it is better to start with a careful consideration of the available fuel itself.

There is a general opinion that for coals with pronounced coking tendencies, having low ash, and a fusion temperature of not less than 2,000 deg. fahr., the underfeed type of stoker, or pulverized fuel firing, is indicated. For anthracite coal, coke breeze and lignite, the forced draft traveling grate stoker is decidedly the choice. For the Midwestern coals, however, whose characteristics are high ash and low fusion temperature of ash, the traveling grate stoker and the pulverized fuel systems seem to share the honors.

The problem of selecting fuel burning equipment for Midwestern coals is briefly analyzed by Mr. Marsh, who has had twenty-five years of active experience in this particular field. The very rapid development of all types of equipment during the past ten years has complicated the selection, but the broad economic basis remains the same. The story is of general interest, since many angles of the problem are similar for other fuels and other localities.

The classification can not be rigid. Particular characteristics of the coal from some certain locality may cause it to burn in quite a different manner from the average coal of the district. Sometimes a clever operator will manage to secure remarkable results with a coal whose characteristics baffle everybody else. In general, however, the characteristics of the available fuel are a major factor in the selection of the equipment for burning it. But there are other factors of sufficient importance to upset a conclusion which would be based on the fuel characteristics alone.

The problem might be a plant involving boiler units of 500 horse-power rating where the load would be rather constant for ten hours out of the twenty-four, with shut-downs over the week end and where exhaust steam would be required for process work. Or, the problem might be for 2,000 horse-power units for a steam electric generating station, and this in turn might be a base load station, or might have to meet the sharp morning and evening peaks common in the public service field. These

plants might be within a stone's throw of each other. The amount of money they have to spend, the quality of labor they will be able to hire, the steam pressure carried; these, and many other items, will affect the selection of fuel burning equipment. In addition, there may be decided prejudices on the part of the buyers that will be paramount to any engineering decisions.

Of the factors that most commonly enter into the selection of fuel burning equipment, the following are usually encountered.

(a) Adaptability of the equipment to the coals
(b) Suitability of the equipment to the load condition
(c) Net operating efficiency
(d) Capacity obtainable
(e) Maintenance
(f) Operating labor cost
(g) Boiler outage

However strong one or more of these factors may be in influencing the final selection, there is, nevertheless, one final analysis that is conclusive. This final analysis interprets and sums up all the factors in one figure, which is, *total cost per thousand pounds of steam* that will be produced by the proposed plant. This should be, and usually is, the objective of all investigations and analyses preceding the selection of fuel burning equipment.

The analysis is particularly interesting as applied to the Middlewest. In this district the chief fuels are those of Illinois, Indiana, West Kentucky and Iowa. These coals are all of relatively high ash content. The ash fuses at low temperatures. It is, therefore, with some care that excessive clinkering is avoided.

Naturally, from a fuel consideration alone, the traveling grate is most suitable. For many years this type of stoker dominated the region dependent upon these fuels. This was on account of the traveling grate's inherent freedom from clinkers due to an undisturbed fuel bed, and to its continuous scavenging of refuse by the grate itself.

Inclined overfeed stokers had rather poor adaptability to these coals. Fuel beds were agitated, causing clinker; avalanching of fuel occurred, due to the steep angle of the grates. This resulted in uneven fuel beds and lowered efficiencies. In addition to these drawbacks, these stokers were of the natural draft type with a low range of flexibility and overload.

Most of the early installations of underfeed stokers on Midwestern coals were handicapped by ignorance of the actual burning characteristics of these coals. Installations were frequently made with grate areas necessitating combustion rates such as would be used on Eastern coals. These combustion rates were too high for Midwestern coals. The stoker was not, in reality, as faulty as the engineering decision which defined its proportions. Some installations actually were forced to use higher grade coals and, in some instances, the stokers were replaced by other types. The underfeed stoker was therefore discredited unjustly for several years as applied to Midwestern coals.

As knowledge of the coals and their firing characteristics became known, more liberal proportioning of stokers became the practise. It is advisable for small stokers of all types to keep combustion rates below 40 lb. of coal per square foot of grate surface per hour. Peaks can, of course, be carried at higher combustion rates. It is not, however, good judgment in selecting fuel burning equipment for small boilers to choose stokers of so small a size that the combustion rate for regular work exceeds 40 lb.

Generally speaking, forced draft stokers, whether traveling grate or underfeed, will burn more coal per square foot of grate than the natural draft stokers. The precise limits which will be guaranteed for any given installation will depend upon the specific features of that installation. Usually these guarantee figures will fall between 40 lb. and 50 lb. of coal per square foot.

The increase in boiler sizes to units of 1500 horsepower and larger, has carried along with it a considerable increase in sizes of stokers. For these large units, the natural draft stokers were out of the picture entirely, as were also the single retort underfeed stokers. Furthermore, there seems to have been a lag in developing the larger sizes of multiple retort underfeed stokers for Midwestern coals.

Starting with the Commonwealth Edison Company installation at Chicago in 1919, the forced draft traveling grate stoker rapidly became most generally accepted as the stoker for central stations and large industrial plants using Midwestern coals. This stoker had zone control, and its capacity for burning Midwestern coal has been demonstrated to be decidedly in excess of 50 lb. per square foot of grate surface per hour. There are no ignition difficulties: the coal does not clinker, and of course this type of stoker is automatically self-cleaning. The zone control of air insures flexibility to meet load conditions.

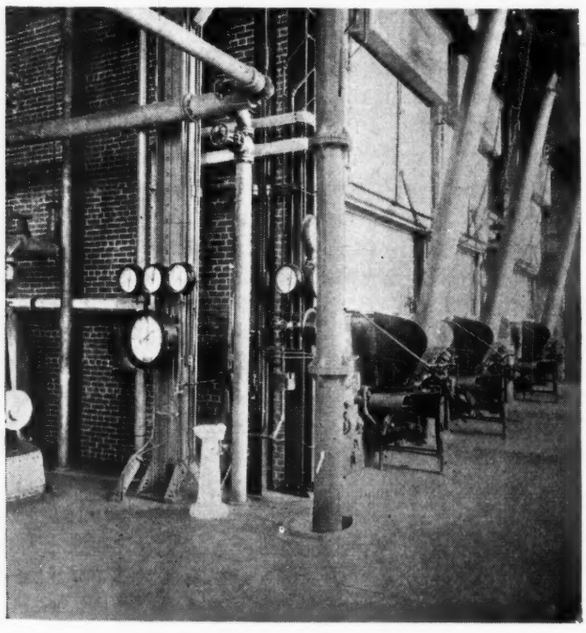
The application of forced draft to the chain grate further increased the utility of this type of stoker. Not alone did it increase capacity and make the stoker more flexible to meet load conditions, but it greatly increased the range of fuels which this stoker could burn economically. Natural draft chain grates were limited to free burning coals. Forced draft chain, or traveling grates can be applied to semi-coking coals, anthracite and coke breeze. Many coals can be well handled on the forced draft chain grate, due to the zoned air control. Therefore, just as the underfeed stoker should be considered in connection with high ash Western coals, so the forced draft chain grate may be considered in many cases where Eastern coal is to be used.

Within the last few years, multiple retort under-

feed stokers have been going through an important development stage. The increase in size of boiler units and the demand for increased ratings have thrown too much burden on the distributing mechanism which was originally designed to meet the requirements of the older and smaller stokers of this class. The coal distributing function of the present day super station type of multiple retort stoker has proved entirely successful, so that stokers of 500 square feet or more of area are perfectly practical. Furnace arrangement has also received much recent attention, and appropriate water cooling of furnace walls has eliminated the old bugbear of clinker troubles at the sides and rear of the stoker. Proper mechanical agitation of the fuel bed and deep retort feeding assure combustion rates in line with those of the traveling grate stoker. Deep clinker grinding pits have successfully solved the question of continuous ash disposal.

Throughout this entire period, the development of pulverized fuel firing progressed rapidly. Considerable apprehension was at first felt that this firing method would not be practical for Midwestern coals due to their high moisture content, high power requirements for pulverizing, abrasiveness, and slagging propensities. These apprehensions were far from being groundless. Each of the problems had to be solved as met in order to make it possible to insure successful pulverized fuel installations with these fuels.

Difficulties due to high moisture were solved by the use of preheated air in the pulverizing mills and



Commercial installation of single retort stokers for burning Midwestern coal in small industrial boiler plant

the complete elimination of coal dryers. This, and improved mill designs reduced the amount of power required for pulverizing. Abrasiveness is inherent to the fuel, but has been reduced by the use of preheated air in mills. It, however, is an item to recognize in considering pulverized fuel equipment for these fuels. Furnace slagging was overcome by proper furnace designs. This entails furnaces of liberal proportions,

Natural draft chain grate stokers

adequate flame travel without impingement on walls, and cooling elements in the furnace so arranged as to reduce the temperatures at points where slagging would ordinarily occur.

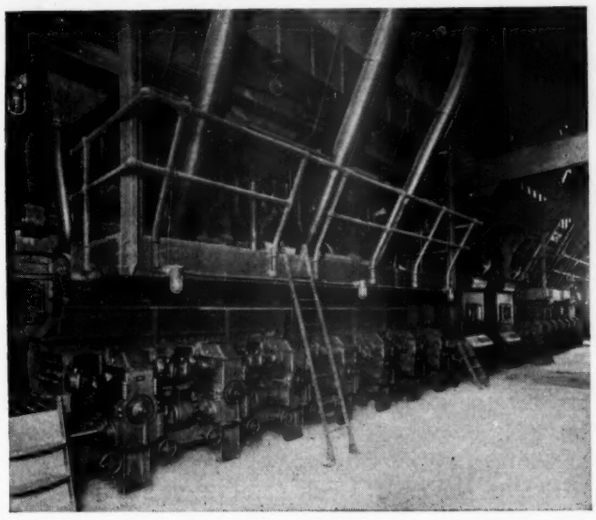
Initial investment and pulverizing costs tended to retard progress at the start. As development progressed, however, many changes and improvements were made. Burner designs were greatly improved; larger mills were developed; the elimination of dryers and the application of preheated air directly to the mills conserved space, reduced initial investment, power costs and mill maintenance.

The success of the large central pulverizing or storage systems soon caused the development of unit systems in the attempt to meet the demands of the smaller installations. Dozens of designs of mills appeared in the field almost simultaneously. As in most development work, the problems were not fully appreciated. At first, numerous attempts were made simply to install pulverized fuel burning equipment with no more liberal provision for furnace than would be required for grates or stokers. Naturally, numerous ill-advised installations were made. Few data were available on pulverizing or maintenance costs and other installations were made where high purchased power costs made the total pulverizing costs unduly high. Due to such adverse effects, development of the unit system of pulverized fuel burning has suffered some definite reactions. However, with a proper engineering analysis of costs and of mill and furnace designs, pulverized fuel installations for burning Midwestern coals can be made very successfully, and will produce excellent results.

Pulverized fuel systems of both the storage and unit types, therefore, are definitely successful with

Midwestern coals where proper economics warrant and where experienced engineering governs design.

The demand for still larger boiler units with air heaters is now bringing new factors into the problem. It seems at first glance as if pulverized coal furnaces



Multiple retort underfeed stokers installed for very large steam boiler units

could most easily expand to meet this demand. But stokers are by no means out of the picture, regardless of the size unit required. Every problem will best be decided strictly on its own merits, without prejudice, in order to reach the proper economic solution.

There are, therefore, the following classes of fuel burning equipment available and adaptable for burning Midwestern fuels:

Forced and natural draft chain grate stokers

Single and multiple retort underfeed stokers

Pulverized fuel, either direct fired or storage system.

Since these various types of equipment are all adaptable to the fuels in question, the selection of equipment cannot be based solely on adaptability to the coals. Further analysis must be made of the suitability to other items including load conditions, net operating efficiency, capacity, maintenance, operating labor, boiler outage and investment charges.

Early in this analysis comes load characteristics. This survey will determine the possibility of operating on fewer units with pulverized coal, for instance, than with stokers. The possibility of avoiding banked boilers should also receive consideration. Next comes the item of efficiencies obtainable over the operating range. Net efficiencies should be used, or if gross figures are used, addition should be made to costs for the auxiliary power required of whatever nature. Capacities obtainable have become a very important item. The rapid increase in size of prime movers entails ever increasing steam demand per generating unit. This, in many instances, determines the type of fuel burning equipment selected.

The item of outage must be given most serious consideration. The larger steam generating units have reached such proportions that one unit with its accessories may represent an investment of half a million dollars. It becomes of prime importance to have the fuel burning equipment of a nature to assure the absolute minimum of difficulty resulting from shut-downs, not so much on account of the maintenance item, as because of the loss of the unit during periods of outage. Initial cost is mentioned last as being a contributory factor. Investment charges enter into the cost of steam and are of major importance, but should not be the deciding factor they often are. The deciding factor should be the summation of all items—the ultimate cost per thousand pounds of steam.

In conclusion, let us consider the evolution of fuel burning equipment in the Middlewest during the last decade. Ten years ago the natural draft chain grate predominated in both the utility and industrial fields. Today most installations use forced draft. Traveling grates are used in the majority of the larger installations, while single retort underfeed stokers have the majority of the installations of 500 rated horse-power and under. Pulverized coal is showing a steady increase in number of installations both large and small.

With these various types of equipment from which to select, and with so many factors bearing on the problem of proper selection, it is logical that the analysis should indicate one type of equipment in one case and another type in another case. In many instances the problem may be comparable with previous cases in which the analysis has been made;

Typical arrangement of unit mill system for burning pulverized coal

yet it is not good engineering to take things for granted. Therefore, it is the part of good engineering to analyze each case as completely as the facts permit before reaching the conclusion as to what type of fuel burning equipment to install.

· NEWS ·

Photo by BLANK & STOLLER

M. S. SLOAN
President-Elect, N.E.L.A.

THE fifty-second annual convention of the National Electric Light Association, held in Atlantic City June 3rd to 7th, was the largest in the history of the Association. More than 11,000 registered attendance was recorded.

M. S. Sloan, President of the New York Edison Company, and past Vice-President of the N. E. L. A., was elected President to succeed P. S. Arkwright. The other officers elected were as follows: A. Alton Jones of New York, First Vice-President; J. F. Owens of Oklahoma City, Second Vice-President; Marshall E. Sampsell of Chicago, Third Vice-President; Edwin H. Gruhl of New York, Fourth Vice-President; P. S. Young of Newark, N. J., Treasurer; Paul S. Clapp of New York, Managing Director; A. Jackson Marshall of New York, Secretary.

The opening festival of "Light's Golden Jubilee" commemorating the fiftieth anniversary of the Edison incandescent light was celebrated at Atlantic City during the week of the convention, as were Atlantic City's Diamond Jubilee and the dedication of the new auditorium. The co-incidental occurrence of these important events added a dramatic and spectacular quality to the occasion that will make this convention a memorable one.

Among the national figures present in connection with these events were Vice-President Curtis and his staff, Sir Esme Howard, British Ambassador, Don Alejandro Padilla Y Bell, Spanish Ambassador, Henry Ford, and a number of United States Senators and Congressmen.

The exhibition held in the new auditorium was almost 25 per cent larger than any previous N. E. L. A. exhibition. It occupied the entire area of the auditorium hall, the largest hall in the world. Two hundred fifty-nine companies were represented and their exhibits in their entirety presented practically all phases of the electrical industry's activities.

The Technical Sessions were well attended and many excellent papers were presented.

AMERICAN BOILER MANUFACTURERS ASSOCIATION

The annual convention of the American Boiler Manufacturers Association was held June 3rd, 4th and 5th at Skytop Lodge, Cresco, Pa.

H. E. Aldrick, Saginaw, Mich., was re-elected President of the Association, and Owsley Brown, Springfield, Ill., was elected Vice-President.

The following members comprise the new Executive Committee: Homer Addams, Geo. W. Bach, S. G. Bradford, H. H. Clemens, J. R. Collette, F. W. Chipman, E. R. Fish, C. E. Tudor, and A. C. Weigel.

STOKER MANUFACTURERS ASSOCIATION

The annual meeting of the Stoker Manufacturers Association was held May 28th at the Hotel Roosevelt, New York City. Seven of the ten member companies were represented. Plans were discussed for the Fall Meeting at Hot Springs, Va., November 11th, 12th and 13th, and the following officers were elected for 1929-30:

President—H. D. Savage, New York.
Vice-President—J. G. Worker, Philadelphia.
Treasurer—F. H. Daniels, Worcester, Mass.
Secretary—William V. McAllister, Detroit

PRODUCTION OF ELECTRICITY

According to the United States Geological Survey, total production of electricity in the first quarter of 1929 was 23,633,000 kw-hr., an increase of 11 per cent over the output for the same period in 1928. Quantities given are based on the operation of all power plants producing 10,000 kw-hr. or more per month, engaged in generating electricity for public use. This increase is further evidence of the consistent advance in power consumption, and is virtually an index of our national prosperity.

D. W. Wilson resigned his position as Vice-President of Dry Quenching Equipment Corporation, New York, effective June 15th and has joined the organization of the M. W. Kellogg Company, Jersey City, N. J., manufacturers of forged piping and containers for high pressures and high temperatures.

Johns Hopkins University, Baltimore, has called attention to the University's course in Gas Engineering. The course is unique in that it places a graduate in Gas Engineering on the same plane as graduation in Mechanical, Civil or Electrical Engineering. Professor Wilbert J. Huff is in charge of the Gas Engineering Department at Johns Hopkins.

NEW CATALOGS AND BULLETINS

Any of the following literature will be sent to you upon request. Address your request direct to the manufacturer and mention COMBUSTION Magazine.

Ash Sluicing System

"Hydrojet Application" is the title of catalog No. 229 which illustrates and describes the Hydrojet System of Ash Removal. The bulletin is well illustrated to show application arrangements which cover a wide range of installation requirements. 12 pages and cover 8½ x 11 — Allen-Sherman-Hoff Co., Philadelphia.

Coal Conveyors

The Webster coal handling system installed in the Field Museum of National History, Chicago, is illustrated and described in a new two color folder, Form 2910. A list of other important Webster installations is included. 4 pages 8½ x 11—The Webster and Weller Manufacturing Companies, 1856 North Kostner Avenue, Chicago.

Coal Crusher

The new Beaumont Triplex crusher is presented in Bulletin No. 200. This crusher employs the two roll crushing principle to reduce large lumps to moderate size. A wedge-shaped plate is located below and between the rolls. This construction gives the added effect of two single roll crushers and fine crushing is secured at a high rate of speed. 8 pages 8½ x 11—R. H. Beaumont Co., Philadelphia.

CO_2 Indicator and Recorder

The Ranarex CO_2 Indicator and Recorder is described in a Folder R 1. This instrument is entirely mechanical. The principle of operation is based on the fact that the specific weight of flue gas increases in proportion to its CO_2 content. No chemicals are used and the device is particularly simple and rugged. The reading is continuous and results are indicated on a wide scale which is easily read. 4 pages 8½ x 11—The Permutit Company, New York.

Feed Water Regulator

The new Bailey Thermo-Hydraulic Feed Water Regulator is described in Bulletin No. 82 dated June 1929. This regulator depends for its operation upon the fact that the volume of a given weight of steam is far greater than the volume of the water from which that steam was made. The principle of operation and method of installation are described in detail. The illustrations are particularly clear and well chosen. 12 pages 7¾ x 10½—Bailey Meter Company, Cleveland, Ohio.

Furnace Walls and Arches

"Modern Furnace Design" is the title of Catalog No. 151 recently issued to illustrate and describe the American Sectionally Supported Air-Cooled Furnace Wall and the American Suspended Arch. Numerous illustrations are included to show details of construction, application arrangements and typical installations. A section of the catalog is devoted to special arch designs for metallurgical furnaces, open hearth furnaces and oil stills. 48 pages 8½ x 11—American Arch Co., New York.

Multiple Retort Stoker

The new C-E Multiple Retort Underfeed Stoker is presented in Catalog MR-1. Numerous illustrations show details of construction and assembly and full page line cuts of typical setting arrangements are included. 16 pages and cover 8½ x 11—Combustion Engineering Corporation, 200 Madison Avenue, New York.

Power Control Valve

The Ashcroft power control valve is presented in a new illustrated Bulletin No. 1525. The principles of operation, advantages and capacities are given. 8 pages 8½ x 11—Consolidated Ashcroft Hancock Company, 100 East 42nd St., New York.

Protective Coatings

Apexior Protective Coatings for preventing corrosion of Power Plant equipment is described in a new Bulletin No. 1170. The corrosion of metal surface in contact with hot water and steam as represented by the internal surfaces of water-tube boiler tubes and drums, steel tube economizers and feed water heaters, is a subject of keen interest to engineers responsible for the design, construction, operation and maintenance of steam plant equipment. The use of Apexior protective coatings is fully described and illustrated. 16 pages and cover 8½ x 11—The Dampney Company of American, Hyde Park, Boston, Mass.

Pulverized Fuel

The Lopulco Unit System for burning pulverized fuel by the direct fired method is described in a new Catalog U-4. Numerous illustrations of equipment and installations are included and seven full page line drawings show various arrangements of boiler and furnace design. 28 pages and cover 8½ x 11—Combustion Engineering Corporation, 200 Madison Avenue, New York.

Pyrometers

The Leeds and Northrup Potentiometer Pyrometers for flue gas temperatures are illustrated and described in Bulletin No. 872. Chapters are devoted to a review of heat losses in flue gases and the loss due to excess air. Various types of pyrometers and thermocouples are shown and described. 16 pages and cover 8½ x 11—Leeds & Northrup Co., Philadelphia, Pa.

Steam Flow Meter

The new Foxboro Steam Flow Meter is described in Bulletin No. 161. The meter is of the velocity type and employs the principle of pressure drop behind a thin plate orifice placed in the steam line. The operation of the meter is explained in detail and several installation arrangements are illustrated and described. 28 pages and cover 5¼ x 7¾—The Foxboro Company, Foxboro, Mass.

Steam Purifier

"The Wet Steam Problem—How to solve it," is the subject of Bulletin No. 106 describing the Hagan Steam Purifier. This Purifier is of the centrifugal type and is simple and compact. "Clean Dry Steam" is interpreted to mean—"Steam whose purity satisfies the requirements of its intended use." And the Hagan Purifier is offered to meet this condition. 24 pages and cover 8½ x 11—Hagan Corporation, Bowman Building, Pittsburgh, Pa.

Underfeed Stoker

The Type K Underfeed Stoker for burning bituminous coal, is applicable to small boilers—up to 200 hp. Catalog K-2 illustrates and describes this stoker. Setting arrangements are included to show the application of this stoker to different types of boilers. 16 pages and cover 8½ x 11—Combustion Engineering Corporation, 200 Madison Avenue, New York.

V—Notch Meters

Bulletin No. 679-a presents a detailed description of the Cochrane V-Notch Meter. The construction and operation of the meter are well covered and illustrations of typical installations are included. 20 pages 8½ x 11—The Cochrane Corporation, 17th St. & Allegheny Ave., Philadelphia.

Water Column and Gage

The Yarnall-Waring Floatless Hi-Lo Alarm Water Columns and the Se-Sure Inclined Water Gages are described in Catalog W G-1802. Cast iron and forged steel water columns are shown for all working pressures up to 1,400 lb. together with vertical and inclined type gages with either round or flat glasses. 24 pages 5 x 8—Yarnall-Waring Company, Chestnut Hill, Philadelphia.

Water Columns

Reliance Safety Water Columns, signals, water gages, gage cocks, floats, gage-glass protectors and illuminators are shown and described in Catalog R. Directions for installation are included. 16 pages 8½ x 11—Reliance Gauge Column Co., 5920 Carnegie Ave., Cleveland, Ohio.

NOTICE

Manufacturers are requested to send copies of their new catalogs and bulletins for review on this page. Address copies of your new literature to

COMBUSTION

200 MADISON AVE., NEW YORK

REVIEW OF NEW TECHNICAL BOOKS

Any of the books reviewed on this page may be secured through In-Ce-Co Publishing Corporation, 200 Madison Avenue, New York.

Steam, Air and Gas Power

By WILLIAM H. SEVERNS, M.S. *and* HOWARD E. DEGLER, M.E., M. S.

THE heat engineering problems of modern steam, air and gas power apparatus, are of daily interest to all power engineers. There exists an enormous amount of material on this broad subject, both in books and in magazines and there are some rather voluminous books covering it. But the busy engineer of today demands brevity and conciseness in his frequently consulted books. There is definite need for a rigorous elimination of that part of the available information which is non-essential. The demand is for a clear statement of principles, for brief definitions, for a selection of practical formulas, for examples of calculation, and for illustration of typical apparatus. And this is exactly the kind of treatment accomplished in this book.

There is a clear and brief discussion of thermodynamic principles and energy cycles. The usual problems of steam, fuels and combustion are discussed with a view of giving such formulas as are necessary for the engineer's daily use. Heat power plants receive adequate treatment in a short chapter, and the principal equipment of the modern plant is divided among several chapters. In each section, typical pieces of equipment are illustrated, described, and the usual calculations relative to their selection are briefly summarized. A separate chapter covers the subject of compressed air, and another one covers internal combustion engines. There is also a selection of convenient tables for reference in connection with the calculations.

The authors describe their work as an elementary text for use in student courses in heat engineering, and it is well executed for that purpose. But its arrangement and its remarkably concise treatment especially recommend the book for the practising engineer's desk as a handy reference. There is no heavy mass of material for the engineer to wade through in his effort quickly to put his finger on a needed formula. Should the reader have forgotten the precise method of applying the formula, there are specific problems neatly worked out, to bring this back to him.

There is no disadvantage in the brevity of the book for the average engineer. It is comparatively seldom that an engineering problem in steam, air or gas power plants requires solution by exhaustive mathematical calculation by all possible methods. Where such procedure is necessary, many sources of information are likely to be consulted, rather than merely one book. The average engineer, for his average problem, requires rather a book of specific formulas, already selected for his purpose, and the omission of such matter as would prevent his quickly finding and confidently using these formulas. This book, then, will nicely fit in with these average, daily needs.

William H. Severns is Associate Professor, and Howard E. Degler is Assistant Professor, mechanical engineering, in the University of Illinois. Their book is the product of a long and intimate contact with the field in which they have written. Their judgment in the selection of material for concise treatment may therefore be accepted with confidence.

The book is standard 6″ x 9″ size and is attractively bound in cloth covers. There is a profusion of useful illustrations. At the end of each chapter there is a list of questions aimed to bring out the valuable features of the text, and thus fit the book for those who wish to instruct themselves by spare time reading. The 425 pages constitute a convenient size volume. The price is $4.00.

The Theory of Heat

By THOMAS PRESTON

IT has been the author's purpose to cover the whole subject in its experimental as well as its theoretical aspect. The book is, therefore, not a text-book for the class room, but an exposition in considerable detail of the theory of heat.

The historical side of the subject has received due attention, and the author has illuminated this part particularly with the wise philosophy of a mature and cultured mind.

Early experiments are not crowded out by the more recent ones. The significance of the early theories of heat as the beginnings of scientific examination by man into the physical world are clearly portrayed.

Dr. Preston published the first edition in 1894; his present 1929 edition has been edited by Mr. J. Rogerson Cotter to include the latest experiments in heat and thus bring the treatment fully up to date. The subject matter constitutes a most carefully compiled reference work of the greatest value to every one to whom a complete knowledge of the theory of heat is necessary or desirable.

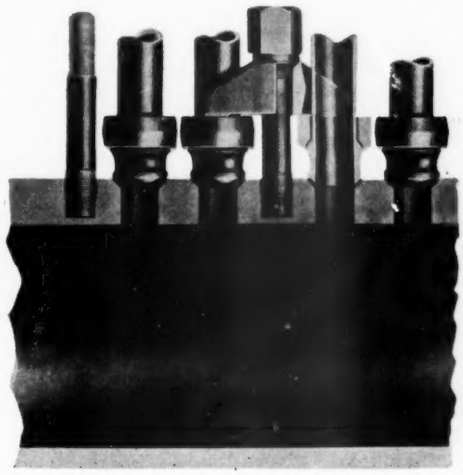
The book is 6 inches by 9 inches in size, has 836 pages, is bound in cloth, and its price is $8.50.

• NEW EQUIPMENT •

High Duty Superheater Headers

THE Elesco Superheater, manufactured by the Superheater Company, New York, consists in general of two headers, one acting as the distributor of saturated steam coming from the boiler and the other as a collector for the steam after it has been superheated, together with the necessary connecting units or elements in which the actual superheating takes place.

Due to recent development leading to high pressures and temperatures, the Elesco high



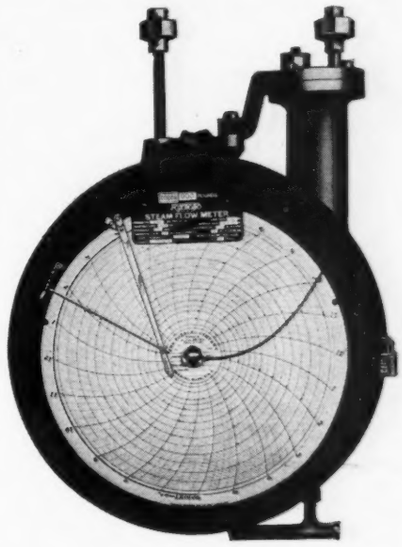
duty superheater header shown above was developed. It consists of an eccentric header turned and bored from a solid forging. This type of header is of rugged construction and quite capable of withstanding high pressures and temperatures. The special treated unit studs are located in the heaviest side of the header, thereby obtaining a uniform stress throughout the cross section. These studs do not extend completely through the wall thickness, in order to eliminate the necessity of maintaining a steam tight threaded joint. The header is usually placed outside the path of the hot gases and in the majority of designs outside of the boiler setting proper, so that they as well as the element joints are accessible for inspection and repair without entering the boiler setting.

The connection between the elements and the header is metal-to-metal, the joints being made so as to permit the easy removal of elements without special tools. The elements have ball shaped ends, made by a special forging process, which set into the seats ground into the header and are held by clamps of forged alloy steel. The joint is especially suitable for high pressures and temperatures making it unnecessary to use handholes opposite the element connections.

Referring to above figure, it will be noted that the only joints to be maintained with this type of header construction are those where the elements come in contact with the header, thus materially reducing the required number of joints as compared with other types of construction.

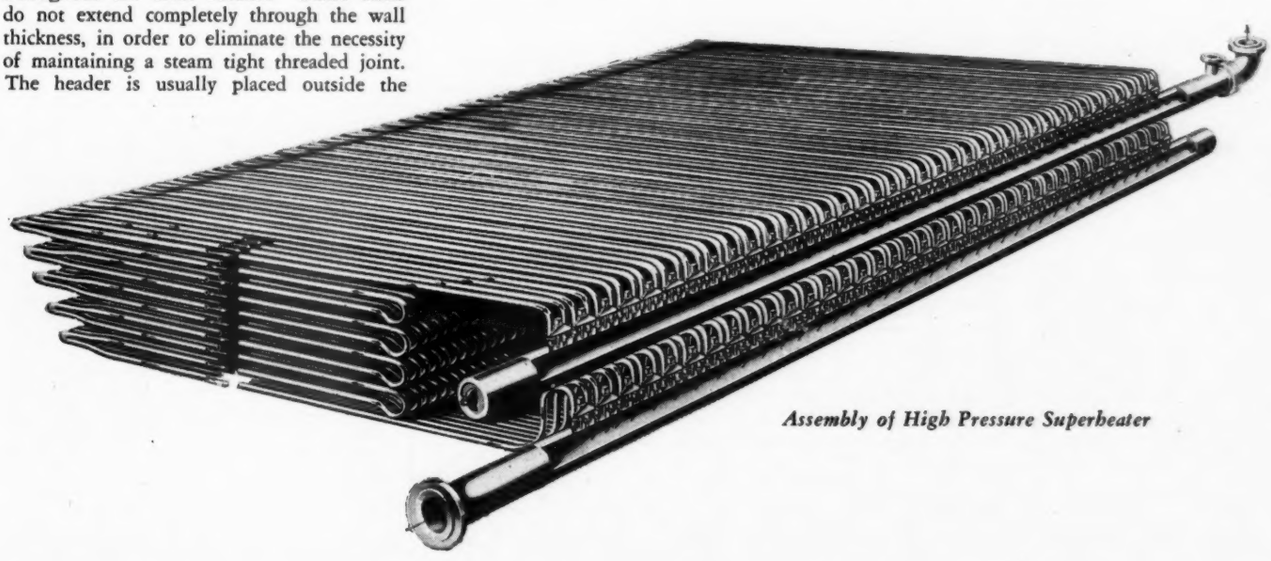
A New Steam Flow Meter With Electric Clock

TO meet the demand for accurate steam flow meters The Foxboro Company of Foxboro, Mass., has built an instrument upon principles that have been accepted throughout the world. The design of the new Foxboro Steam Flow Meter is based on that of the



Foxboro Orifice Meter which has been extensively used for many years for the measurement of gas flow under field conditions where a rugged, simple mechanism of high precision is necessary.

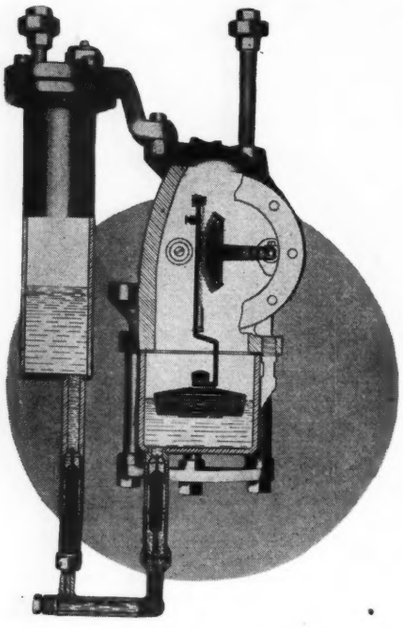
The instrument is calibrated to read and record in terms of steam flow and is equipped with an integrator that reads directly without multipliers, in total pounds of steam that have passed through the pipe. The integrator is a simple, accurate, dependable mechanism driven by an electric clock, or a spring-wound clock if preferred. Once each minute it adds on the counter the number of pounds of steam that have flowed through the pipe during that minute. For example, if steam is flowing at a rate of 56 lb. per minute, the integrator will add



Assembly of High Pressure Superheater

56 to the total indication of pounds of steam. The chart reads directly in pounds per hour.

This new meter is fundamentally accurate because (a) it is of a simple mechanical design in which friction is reduced to a minimum and (b) a large, powerful float is employed, the motion of which is transmitted without angularity (harmonic motion), and (c) because the steam coefficients were carefully determined by us after extensive research and experimentation covering a period of years. This program of research



included a complete series of steam flow tests at the Massachusetts Institute of Technology.

The new meter is a single unit. It has no electrical devices, special compensators, balances or stuffing boxes, and requires no maintenance except to change the chart and ink the pen.

Electric Motor Drive *for* Single Retort Underfeed Stokers

THE Type E and Type K Underfeed Stokers, manufactured by Combustion Engineering Corporation, New York, are usually steam driven. An electric motor drive has recently been developed which is applicable to either of these stokers and may be used wherever the steam drive is impractical, as for instance, where the operating steam pressure is below 60 pounds per square inch.

The electric drive may be briefly described as follows:—the drive consists of a double

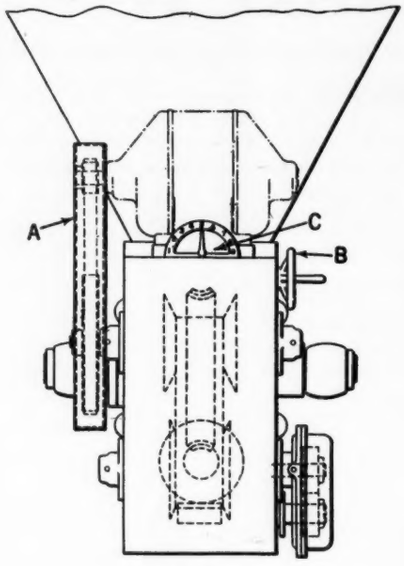


FIG. 1

worm gear reduction unit and a Reeves variable speed transmission unit. The gear case assembly is very compact. All parts are fully encased, yet readily accessible. The motor is located on the flat, top surface of the gear case which provides a convenient and solid

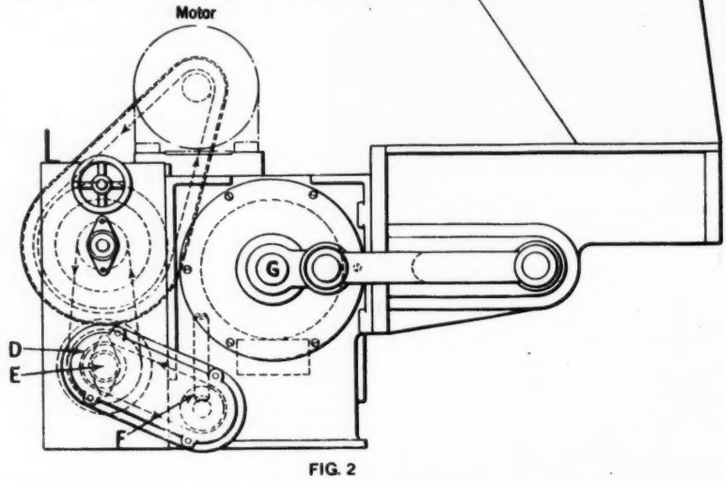


FIG. 2

support. Furthermore, in this position the motor is well removed from the usual floor dirt of the boiler room and is out of the way when the floors are washed. Access to the fire doors is not hindered in any way.

The Reeves mechanism is driven by a silent chain from the motor as shown by A in Fig. 1. On the opposite side at B, is the handwheel, conveniently located, for adjusting the speed changes. The ratio of speed change is from 1 to 8, which is ample for the usual range of combustion rates. For indicating the relative speed, a pointer device is mounted as shown at C.

Fig. 2 shows the side view arrangement. A silent chain drive, D, connects the lower shaft, E, of the Reeves mechanism with the first worm gear reduction, F, from which power is transmitted through the double set of worm gears to the crank shaft, G. Fig. 3 is a plan view. On each end of crankshaft G are cranks H, from which twin connecting rods transmit power to the under side of the pusher block of the stoker. A safety device, in the form of a shear key, is provided to protect the stoker mechanism from breakage in case the stoker feed is obstructed in any way. This shear key, located at K, is particularly convenient for replacement, since it is on the outside of the casing.

When a steam pressure regulator is used to secure automatic control of the stoker speed, a lever is substituted for the handwheel control of the Reeves drive.

The power required to drive either the Type E or Type K Stoker is quite low. Inasmuch as high speed motors are often preferable on account of their lower cost, the electric drive has been designed so that it is applicable to the use of either high-speed or low-speed motors.

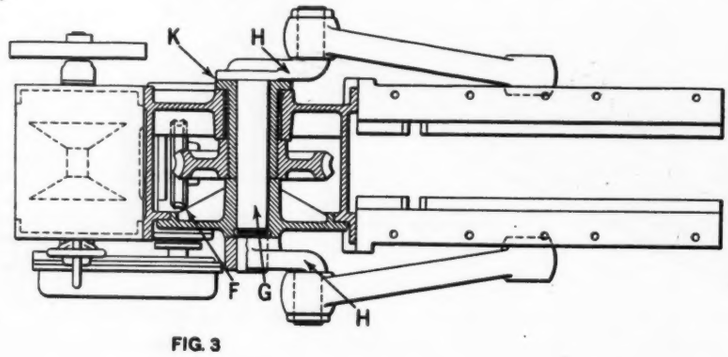


FIG. 3

NOTICE

Manufacturers of equipment will cooperate in the news value of this section by sending us promptly their notices of new products with appropriate illustrations. The articles printed above are a sufficient sample of the material required. Our readers appreciate an early story of new products.

PATENTS

Recently granted, and of General Interest

Printed copies of Patents are furnished by the Patent Office at 10 cents each. Address the Commissioner of Patents, Washington, D. C.

United States Patents
Issued May 14, 1929

1,712,497. Apparatus for regulating the working of steam-generating plants. Otto H. Hartmann and Friedrich Wempe, Cassel-Wilhelmshohe, Germany, assignors to Schmidt'sche Heiss dampf-Gesellschaft m. b. H., Cassel-Wilhelmshohe, Germany. Filed Mar. 16, 1925, and in Germany Mar. 28, 1924.

1,712,509. Closure apparatus. Charles F. Miller, Moore, Pa., assignor to Westinghouse Electric & Manufacturing Company of Pennsylvania. Filed Apr. 13, 1928.

1,712,527. Fan construction. Philipp Suter, Baden, Switzerland, assignor to Aktiengesellschaft Brown, Boveri & Cie., Baden, Switzerland. Filed Jan. 25, 1926, and in Germany Feb. 2, 1925.

1,712,559. Process and apparatus for preheating feed water. Emil F. Holinger, New York, N. Y., assignor by mesne assignments, to Hudson Electrical Heating Corporation, New York, N. Y. Filed Aug. 4, 1926.

1,712,589. Concentrator. Albert H. Stebbins, Los Angeles, Calif. Filed Apr. 28, 1927.

1,712,614. Locomotive Boiler. Charles Gilbert Hawley, Cleveland, Ohio, assignor to Locomotive Firebox Company, Chicago, Ill. Filed Apr. 8, 1926.

1,712,615. Locomotive Boiler. Charles Gilbert Hawley, Chicago, Ill., assignor to Locomotive Firebox Company, Chicago, Ill. Filed Oct. 3, 1924.

1,712,806. Steam generator. William E. Baker, Erie, Pa. Filed Mar. 28, 1924.

1,712,810. Heating apparatus. Charles L. Bryant, Cleveland, Ohio. Filed Oct. 15, 1925.

1,712,849. Furnace wall. Charles E. Sharp and Clarence A. Strachota, Mexico, Mo., assignors by mesne assignments, to Bigelow-Liptak Corporation, Detroit, Mich. Filed Apr. 27, 1925.

1,712,857. Boiler. Gustave Trasenster, Ougree, near Liege, Belgium, assignor to the Societe Anonyme d'Ougree Marihaye, Ougree, near Liege, Belgium. Filed July 24, 1922, and in Belgium Mar. 13, 1922.

1,712,892. Heat-exchange apparatus. Gregory D. Mantle, Pittsburgh, Pa., assignor to Mantle Engineering Company of Pennsylvania. Filed Apr. 9, 1926.

1,712,902. Steam valve. Pasquale Pascale, New York, N. Y., assignor to Dri-Steam Valve Corporation of Delaware. Filed Nov. 12, 1925.

1,712,919. Furnace. Isaac Harter, Dongan Hills, N. Y., assignor, by mesne assignments, to Fuller Lehigh Company of Delaware. Filed Dec. 16, 1925.

1,712,928. Locomotive arrangement. Neal T. McKee, Bronxville, N. Y., assignor to American Throttle Company, Inc., New York, N. Y. Filed Dec. 8, 1926.

1,712,933. Fuel Economizer. John A. O'Connor, Canton, Ohio. Filed Aug. 29, 1928.

1,712,972. Method of forming blanks for making seamless tubes. Ralph C. Stiefel, Ellwood City, Pa. Filed Nov. 8, 1927.

1,712,999. Method of and apparatus for burning pulverized fuel. Henry Kreisinger, Pittsburgh, Pa., and John Anderson, Milwaukee, Wis., assignors to Combustion Engineering Corporation of New York. Filed Apr. 26, 1922.

1,713,032. Apparatus for use in drying and distilling lignite, peat, noncoking coals, and other similar carbonaceous matter. Hubert Debauche, near Charleroy, Belgium. Filed July 6, 1927, and in Great Britain July 20, 1926.

1,713,091. Superheater. Arthur D. Pratt, Short Hills, N. J., assignor to The Babcock & Wilcox Company, Bayonne, N. J. Filed Oct. 23, 1924.

1,713,176. Water-tube boiler. Odoardo Giannelli, Empoli, Italy. Filed Dec. 17, 1924, and in Italy Jan. 2, 1924.

1,713,237. Drier. William T. Morin, Los Angeles, Calif., assignor to Pacific Abrasive Supply Company, Los Angeles, Calif. Filed Jan. 11, 1928.

1,713,270. Single-roll wet mill. Henry Drysdale, Wandsworth, London, England. Filed June 11, 1926, and in Great Britain Mar. 19, 1926.

1,713,297. Centrifugal air-float pulverizer. Otto Olston, Chicago, Ill. Filed Mar. 26, 1928.

1,713,298. Single-tank boiler washing and filling apparatus. Spencer Otis, Barrington, and Frank S. Wichman, Highland Park, Ill., assignors to National Boiler Washing Company, Chicago, Ill. Filed Oct. 19, 1922.

1,713,322. Chain grate for furnaces. Alfred William Bennis, Little Hulton, Bolton, England. Filed Jan. 26, 1927, and in Great Britain Jan. 21, 1926.

1,713,327. Hammer mill. George W. Borton, New Lisbon, N. J., assignor to Pennsylvania Crusher Company, New York, N. Y. Filed Feb. 14, 1928.

1,713,345. Boiler plug. Peter E. McIntosh, Kalamazoo, Mich., assignor of one-eighth to Charles R. Allen, Kalamazoo, Mich. Filed Feb. 19, 1926.

1,713,355. Hinged cage for grinders. Harry J. Shelton, University City, Mo. Filed Mar. 2, 1928.

1,713,400. Fuel saver or economizer. Herman Schaperjahn, Closter, N. J. Filed Dec. 2, 1927.

1,713,487. Mill for fine grinding. John Rowland Torrance, Bitton, England. Filed Oct. 1, 1923, and in Great Britain, Oct. 17, 1922.

United States Patents
Issued May 21, 1929

1,713,507. Hammer mill. Charles D. Ammon, Lincoln, Nebr. Filed Aug. 16, 1928.

1,713,508. Automatic furnace apparatus. Roger Marcel Andre, Fontenay-sous-Bois, France. Filed Nov. 2, 1926, and in France Nov. 17, 1925.

1,713,530. Fuel. Grant Hammond, Whitneyville, Conn., assignor to Fuel Development Corporation of Delaware. Filed Mar. 15, 1926.

1,713,566. Furnace. John F. O. Stratton, Chicago, Ill. Filed Aug. 28, 1925.

1,713,593. Feeding device. Edward M. Brennan, Springfield, Ohio, and Erwin H. Hussey, Minneapolis, Minn., assignors to The Bauer Brothers Company, Springfield, Ohio. Filed Mar. 8, 1928.

1,713,609. Removable segment for crusher rolls. George Edward Krider, Hollidaysburg, Pa., assignor to McLanahan-Stone Machine Company, Hollidaysburg, Pa. Filed Oct. 5, 1927.

1,713,718. Method and means for removing furnace residues. Max Schwabach, Berlin-Halensee, Germany. Filed Sept. 15, 1925, and in Germany Sept. 23, 1924.

1,713,729. Steam or hot-water generator for use in heating systems. Elmer R. Williams, Springfield, Mo. Filed Apr. 29, 1926.

1,713,767. Apparatus for removal of soot from the smoke boxes and fire tubes of marine and like boilers. Norman Emile McClelland, London, England. Filed July 5, 1923, and in Great Britain Nov. 16, 1922.

1,713,817. Method of burning solid fuel. Alfred Cotton, St. Louis, Mo.; Laura P. Cotton executrix de bonis non of said Alfred Cotton, deceased. Filed Sept. 11, 1922.

1,713,840. Method of and apparatus for carbonizing coal and like material. Irving F. Laucks, Seattle, Wash., assignor, by direct and mesne assignments, to Old Ben Coal Corporation, Chicago, Ill. Filed June 23, 1920.

1,713,880. Air cleaner. Augustus L. McLean, Asheville, N. C. Filed Aug. 17, 1927.

1,713,881. Method of making conduits. Charles H. Seifert, Barberton, Ohio, assignor to The Babcock & Wilcox Company, Bayonne, N. J. Filed Oct. 9, 1926.

1,713,956. Boiler platform. Louis Diven, Cynwyd, Pa., assignor to The Babcock & Wilcox Company, Bayonne, N. J. Filed Aug. 4, 1925.

1,713,957. Pulverizing mill. Samuel Duvall, Chicago, Ill. Filed June 20, 1928.

1,713,962. Collapsible draw mandrel. Julius Grossweischede and Georg Reichenbecher, Mulheim-on-the-Ruhr, Germany, assignors to Vereinigte Stahlwerke Aktiengesellschaft, Dusseldorf, Germany. Filed Jan. 24, 1927. Renewed Mar. 20, 1929.

1,714,005. Garbage or refuse incinerator. William F. Drew, Los Angeles, Calif. Filed Jan. 2, 1925.

1,714,060. Apparatus and process for making cement. John E. Velzy and Walter T. Groner, Dayton, Ohio, assignors to Southwestern Portland Cement Company, Dayton, Ohio. Filed Apr. 20, 1928.

1,714,080. Pulverizing apparatus. Ollison Craig, Worcester, Mass., assignor to Riley Stoker Corporation, Worcester, Mass. Filed Dec. 15, 1927.

1,714,116. Locomotive-stoking mechanism. David T. Williams, New York, N. Y. Filed Sept. 7, 1927.

1,714,128. Apparatus for burning pulverized fuel. Gustav Henry Kaemmerling, Allentown, Pa., assignor, by mesne assignments, to Fuller Lehigh Company of Delaware. Filed Aug. 19, 1925.

1,714,132. Pulverizer. Joseph Molz, Oberhausen, Germany, assignor to The Babcock & Wilcox Company, Bayonne, N. J. Filed June 30, 1923, and in Germany Aug. 14, 1922.

1,714,168. Plant for utilizing the sensible heat of hot coke. Oswald Heller, Halensee, near Berlin, Germany. Filed Sept. 29, 1924, and in Germany Oct. 3, 1923.

1,714,179. Method and apparatus for the treatment and utilization of superheated steam. John R. McDermet, Jeannette, Pa., assignor to Elliott Company, Pittsburgh, Pa. Filed July 13, 1923.

1,714,312. Disintegrating apparatus. Joseph E. Kennedy, New York, N. Y. Filed Mar. 31, 1924.

1,714,432. Furnace utilizing forced draft. Elmer Amos McArthur, Flint, Mich. Filed Feb. 16, 1927.

United States Patents
Issued May 28, 1929

1,714,505. Locomotive boiler and method of operating the same. Otto H. Hartman, Cassel-Wilhelmshohe, and Wilhelm Jung, Cassel, Germany. Filed May 9, 1925, and in Germany May 14, 1924.

1,715,506. Brick and cement for furnace use. Russell P. Heuer, Philadelphia, Pa., assignor to General Refractories Co. of Penn. Filed December 29, 1924.

1,714,577. Chain grate. John Van Brunt, Flushing, N. Y., assignor to Combustion Engineering Corp. of N. Y. Filed Jan. 28, 1925.

1,714,598. Composition of matter. Ralph M. Hardgrove, Allentown, Pa., assignor to Fuller Lehigh Co., Fullerton, Pa. Filed May 17, 1927.

1,714,600. Furnace and boiler. George P. Jackson, Flushing, N. Y., assignor to Combustion Engineering Corp. of N. Y. Filed Jan. 16, 1925.

1,714,673. Boiler furnace. George P. Jackson, Flushing, N. Y., assignor to Combustion Engineering Corp. of N. Y. Filed Sept. 10, 1929.

1,714,678. Burning of fuel. Henry Kreisinger, Piermont, N. Y., assignor to Combustion Engineering Corp. of N. Y. Filed Oct. 11, 1924.

1,714,695. Air-heating apparatus. William A. Rowe, Detroit, Mich., assignor, by mesne assignments, to American Blower Corp. of Detroit. Filed Aug. 22, 1925.

1,714,735. Vacuum and boiler-feed pump. Benjamin Skidmore, Jr., Glencoe, Ill., assignor to Minette E. Skidmore, Chicago, Ill. Filed July 18, 1927.

1,714,829. Steam boiler. Ernest H. Vincent, Oakland, Calif. Filed June 1, 1923.

1,714,853. Apparatus for drying, charring, and otherwise treating loose material. Otto Dobblestein, Essen, Germany; Keroline Dobblestein executrix of said Otto Dobblestein, deceased. Filed Mar. 29, 1926, and in Germany Apr. 4, 1925.

1,714,893. Method of and means for conveying fluids. Arthur R. Smith, Schenectady, N. Y., assignor to General Electric Company of N. Y. Filed Nov. 24, 1926.

1,714,925. Steam trap. Erik Sixten Sandberg, Skutskar, Sweden. Filed Sept. 6, 1927 and in Sweden Nov. 17, 1926.

1,714,977. Underfeed stoker. Robert A. Foresman, Moores, Pa., assignor to Westinghouse Electric & Manufacturing Company of Penna. Filed Jan. 26, 1925.

1,715,007. Air heater. Arthur E. Reuss, Cincinnati, Ohio, assignor to the General Iron Works Company of Cincinnati. Filed Oct. 3, 1927.

1,715,022. Valve-controlling apparatus. John O. Woodsome, New York. Filed June 16, 1926.

1,715,037. Economizer. Howard J. Kerr, Westfield, N. J., and James E. Trainer, Barberton, Ohio, assignors to The Babcock & Wilcox Company, Bayonne, N. J. Filed Jan. 24, 1927.

1,715,068. Drum-connection joint. William A. Jones, West New Brighton, N. Y., assignor to The Babcock & Wilcox Company, Bayonne, N. J. Filed Jan. 23, 1922.

1,715,123. Apparatus for pulverizing materials. William T. Doyle, Boston, Mass., assignor to Sturtevant Mill Company of Boston. Filed Oct. 1, 1928.

1,715,137. Soot-cleaner-operating mechanism. Frederick W. Kinaker and Theodore M. Bruback, Du Bois, Pa. Filed Apr. 25, 1923.

1,715,139. Furnace. Edwin Lundgren, Frederick, Md., assignor to Combustion Engineering Corp. of N. Y. Filed July 2, 1923.

United States Patents
Issued June 4, 1929

1,715,378. Radiator. Thomas E. Murray, Brooklyn, N. Y. Filed May 1, 1924.

1,715,516. Air-inlet attachment for combustion chambers. Friederick Sette, Detroit, Mich. Filed Sept. 14, 1927.

1,715,584. Method and apparatus for burning fuel. Earl P. Wetmore, Concord, Mich., assignor to The Anoilcoal Burner Co., Toledo, Ohio. Filed Oct. 23, 1924. Renewed Mar. 17, 1928.

1,715,614. Baffle for boilers, stills, and the like. Charles P. Mills, Pittsburgh, Pa., assignor to The Duraloy Company, Pittsburgh, Pa. Filed Mar. 15, 1927.

1,715,677. Rotary siphon device for steam drums. Harry R. Ritchie, Springfield, Mass., assignor to A. W. Holbrook, Inc., Palmer, Mass. Filed Aug. 31, 1928.

1,715,724. Pulverizer. Ayers F. Thompson, Sunland, Calif. Filed June 13, 1927.

1,715,729. Drier. Dixon E. Washington, Kansas City, Mo., assignor of one-half to Willard B. Connell, Kansas City, Kans. Filed July 25, 1927.

1,715,772. Grinding plate for attrition mills. William H. Mechlin, Springfield, Ohio, assignor to The Bauer Brothers Company, Springfield, Ohio. Filed Sept. 26, 1927.

1,715,830. Aeration process for drying, carbonizing, and oxidizing plants and apparatus therefor. Robert Glinka, Mulheim-Ruhr, Speldorf, Germany. Filed Oct. 13, 1927, and in Germany Oct. 18, 1926.

1,715,852. Material drier. Martin Madsen, Monterey Park, Calif., assignor to Madsen Iron Works, Huntington Park, Calif. Filed Oct. 11, 1926.

1,715,919. Boiler water preheater. John Hatch, Gold Pines, Ontario, Canada. Filed Feb. 24, 1928.

1,715,954. Incinerator. Albert A. Schuetz, Milwaukee, Wis., assignor to Home Incinerator Co., Milwaukee, Wis. Filed Mar. 5, 1927.

1,715,961. Furnace. Edward Tschira, Detroit, Mich. Filed Mar. 19, 1928.

1,716,071. Distributor for automatic stokers. Angus MacArthur, Chicago, Ill., assignor to The Koppers Company, Pittsburgh, Pa. Filed Oct. 4, 1923.

The Value of Patents

There were over 3,500 patents issued by the United States Patent Office for the four weekly periods of May 14th to June 4th. Out of all these, we have culled 92 patents that are related to combustion and allied activities, and have printed the titles and other information for the convenience of our readers.